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FINAL REPORT

DETERMINATION OF PROCESSING AND TEST FACILITY REQUIREMENTS FOR LARGE SOLID ROCKET MOTORS

VOLUME II: TASK II

FACILITY OPTIMIZATION

by:

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AEROJET SOLID PROPULSION COMPANY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA Lewis Research Center

Contract NAS3-12041

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Prepared for:

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ABSTRACT

An overall processing plan, delineating optimum facilities and equipment requirements, was developed for the processing and static testing of full-length 260-in. (6.6 m)-dia solid rocket motors at the Aerojet-General Corporation's Dade County, Florida, plant. Two program phases were considered---processing and static testing eight motors in 2.5 years, and processing, but not testing, 30 motors in 5 years. For the eight-motor program, an additional cast-cure-test facility would be required to meet the schedule. Motor case on-plant movement and case insulation would be accomplished in the manner previously defined for a single-motor program. Major expansion and improvements for propellant raw materials storage and handling are emphasized. A permanent and fully-equipped test facility installation would be provided in support of both cast-cure-test caissons.

For the 30-motor program, the key factors were the logistics of motor case processing and efficient utilization of the two cast-cure-test caissons. Repetitive moves of the motor justified the placement of a new insulation facility between the receiving area and the casting facilities. Requirements of a canal extension and large lifting facilities for loaded motor shipping obviate special facilities for moving and lifting the empty cases. To assure adequate propellant production rates, an additional vertical batch mix station would be provided. Igniter processing facilities are justified in this program phase.

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I. SUMMARY

This report is the second of two volumes of the final report for Contract NAS3-12041, Determination of Large Solid Rocket Motor Processing and Test Facilities Requirements. This volume presents the results of Task II, Facility Optimization, which determines the optimum facilities, on the basis of minimum cost per motor, for the processing and static test firing of full-length 260-in. (6.6 m)-dia solid rocket motors, each containing 3,400,000 lb (1,542,000 kg) of propellant and equipped with a nozzle thrust vector control system. Phase A pertains to the processing and static test firing of eight motors in a period of two- and one-half years, while Phase B applies to the processing, but not static test firing, of 30 motors in a period of five years. Included are the definition of facilities, related costs, and detailed process plans. New facilities and equipment are defined, as well as modifications to existing facilities and equipment at the Aerojet-General Corporation's plant in Dade County, Florida.

In Phase A, it was assumed that four motor cases would be provided, each to be rehabilitated and reused once, and that all facility modifications defined in Task I of this contract would be existent. The required span times for major operations in the cast-cure-test caisson were summarized and showed that the schedule could not be attained without providing an additional caisson. An overall process schedule was developed for two caissons which would allow processing without interference.

On-plant movement of the motor cases would be similar to that selected for Task I. The cases would be received on-plant at a dock on Canal C-111, then moved on a transporter by road to the insulation facility. The road from the dock to the cast-cure-test area would be upgraded by the construction of an asphaltic concrete surface.

There would be no major facility improvements required for insulation of the motor cases for the eight-motor program. The environmental building

I. Summary (cont)

provided for the Task I program would be adequate, depending on the age and maintenance of the wood structure. Insulation rehabilitation required for the reuse of the chambers would be accomplished partially in the caisson prior to hydrotest and partially at the insulation facility.

The propellant raw materials lot quantities and production run frequencies for Phase A result in requirements for storage and in-process handling facilities and equipment. Included are bulk handling containers and storage buildings for the oxidizer and aluminum powder, storage tanks for binder polymer and plasticizer, and various dispensing improvements. No significant changes in oxidizer preparation or propellant mixing facilities are required.

An improved bayonet casting process was devised to accommodate multiple-bayonet controlled tip submergence requirements. This concept features highly flexible bayonet tubes and horizontally-adjustable casting pot stands.

Movable buildings for the cast-cure-test caissons were designed to be more easily moved than the current building and to be compatible with the revised casting process and the loaded motor lifting equipment expected for Phase B.

New static test facilities would be required to support both CCT locations, including buildings for nozzle/TVC checkout, instrumentation operations, inert storage, and offices. The existing control room and instrumentation center would be expanded to include additional equipment and a new terminal room would be provided to serve both test sites. Similarly, thrust vector control system support equipment and hydrotest support equipment would be either centrally located or portable for common usage. A pyrotechnic magazine is required for storage of igniters and ignition system components. The total estimated cost of Phase A facility additions would be $7.9 to 8.1 millicn.

I. Summary (cont)

In Phase B, no static testing is required, but the motors would be assembled to include essentially all stage hardware in preparation for delivery. Movement of loaded motors was specifically not included in this study, but definition of the interface with subsequent operations requires consideration of the facilities that would be available for loaded motor handling. It was assumed that all necessary motor hardware would be available at two-month intervals during the five-year 30-motor program and that all facilities specified for the Phase A program would be existing at the start of the Phase B motor processing schedule.

Cost-optimization for Phase B was found to be contingent upon adapting the process cycle to the then-existing two CCT caissons, since each caisson and the attendant complex of facilities make up the largest cost units, particularly when considering the effect on loaded motor handling and transport facilities. These facilities are expected to include extension of the existing Canal C-111 to each caisson and the installation of a 2000-ton (1,800,000 kg) double-boom stiff-leg derrick at each casting site. Therefore, movement of the motor cases to the casting site and lifting into the caisson would utilize the same facilities. A new case insulation facility would be located on the canal extension to eliminate the repetitive road movement of this large load, which includes the loaded-motor handling rings. No changes in the basic insulation processes and equipment are required.

Because of the shorter processing cycle for Phase B, the quantity of bulk handling containers for oxidizer would be increased to accommodate two propellant raw material lots. An additional vertical batch mix station would be needed to assure adequate reserve in propellant production capacity. The mixing rate available from three batch mixers and the continuous mixer could be supported by pregrinding a five-day supply of oxidizer and by utilizing an existing unused tank for premix dispensing.

I. Summary (cont)

The larger Phase B motor handling rings require that the environmental shrouds in the cast-cure-test caisson be of greater diameter. The cast and cure processes and facilities are otherwise similar to the Phase A requirements, except that the facility conversion for static testing is eliminated. Motor build-up through stage assembly would be implemented by preparation of major subassemblies.

Installation of complete ignition system processing and storage facilities is justifiable on the basis of overall cost, because of available production propellant and advantageous utilization of labor during the slack periods of the motor processing cycle.

The total estimated cost of the Phase B facility additions is $3.5 million.

II. INTRODUCTION

A. PURPOSE OF REPORT

This report is the second of two volumes of the final report for Contract NAS3-12041, Determination of Processing and Test Facility Requirements for Large Solid Rocket Motors, performed by the Aerojet Solid Propulsion Company (ASPC) for the Lewis Research Center, National Aeronautics and Space Administration. The work reported in this volume encompasses Task II, Facility Optimization for Full-Length 260-In.-Dia Motor Processing and Testing.

B. BACKGROUND

The Aerojet-General Corporation's plant in Dade County, Florida, has been utilized successfully in the processing and static test firing of three 260-in. (6.6 m)-dia short-length solid rocket motors. While the facilities

II.B. Background (cont)

were adequate for their intended use, the potential requirement for processing and testing larger motors equipped with nozzle thrust vector control systems would necessitate facility modification and expansion. The present facility consists of propellant processing stations with associated support buildings and a Cast-Cure-Test caisson. The caisson is capable of containing much larger motors, but modifications would be necessary for support of a longer motor and for measurement of side forces resulting from thrust vectors during static testing. Consideration must be given to propellant production adequacy with respect to reserve capacity in the event of equipment breakdown. In addition, the quantity and rate of production of motors will influence the type and magnitude of facility expansion.

C. PROGRAM OBJECTIVE

The objective of this program was to define the extent and associated cost of the modifications of the Dade County Plant (DCP) facilities required to process and static test fire 260-in.-(6.6 m)-dia solid rocket motors containing at least 3,400,000 lb (1,542,000 kg) of solid propellant and equipped with a nozzle thrust vector control system. Acceptability of the modifications were based on their low cost and final facility adequacy to process the required motors.

D. SCOPE OF WORK

Task II of the program was directed toward the definition of optimum facilities, on the basis of minimum cost per motor, for two program phases. Phase A applies to the cast, cure, and static test of eight full-length 260-in. (6.6 m)-dia motors in a period of two- and one-half years. The Phase B program is to cast and cure, but not static test, 30 full-length motors in a period of five years. Based on the information developed in Task I and on previous 260-in.-(6.6 m)-dia short-length motor processing and testing experience,

II.D. Scope of Work (cont)

overall process plans were developed, describing all required operations. New facilities and equipment requirements and modifications to existing facilities and equipment were delineated along with attendant costs. All operations from the receipt of the motor case on-plant to assembly and static test firing, or preparation for delivery, were considered. Movement of the loaded motors was specifically not within the scope of this effort.

E. MOTOR DEFINITION

The 260-in. (6.6 m)-dia solid rocket motor selected for reference use in this program is the design presented in Reference (a), the Saturn IB Improvement Study, Phase II, by the Douglas Missile and Space Division. This motor contains 3,400,000 lb (1,542,000 kg) of propellant and is equipped with a liquid-injection thrust vector control system (LITVC) on an 11:1 expansion ratio conic nozzle. Motor design and processing details were provided under subcontract by Aerojet. Later, design studies by Aerojet indicated equivalent performance could be achieved with a contoured 9:1 expansion ratio nozzle, and that movable nozzles, including those with flex-seals, were attractive alternatives, a version of which is shown in Figure 1. In addition, the fore-end ignition system employed in that design was a departure from the aft-end mounted igniters of 260-SL motor experience. Therefore, processing and test requirements of the principal design alternatives were considered in this study.

F. COST ESTIMATES

Cost estimates for facilities shown in this report are in 1970 dollars and are based on the assumption of government expendititure through Aerojet. Actual construction is assumed to be accomplished by outside contractors, so that to the estimated direct costs are added contractors' fee and profit and direct charges for Aerojet engineering and drafting services. Accuracy of the estimates is commensurate with the scope of the study effort and are probably valid at least within ten percent.

III. PHASE A - EIGHT MOTOR PROGRAM

A. STUDY CRITERIA AND GROUND RULES

The objective of this phase is to define the optimum facilities required to cast, cure, and static test fire eight full-length 260-in. (6.6 m)-dia solid rocket motors in a period of two-and-one-half years. The criteria for facility acceptability is their adequacy for producing high-quality large motors at minimum cost. Optimization is on the basis of minimum overall cost per motor for this phase only.

To implement the criteria for Phase A, a limited number of constraints were established for developing the process plan and defining the scope of facilities requirements.

1. It is presumed that the facilities additions and modifications defined for Task I would be existent and would have been demonstrated to be adequate for that program.

2. A total of four motor cases would be delivered to the plant on essentially an as-required schedule. Each case would be used for two motor tests, requiring rehabilitation and hydrotest following the initial test. The re-use of each case is a probable approach to cost reduction on a program of this type. The hydrotest requirement for a tested motor case is a question of engineering philosophy and is not necessarily recommended here, but simply added as a possible complication to be considered.

3. All processing and testing operations would be performed nominally with three work shifts on a five-day week. Operations which are necessarily continuous in nature, such as casting, curing, and temperature conditioning, would be performed on a seven-day week at the appropriate work level.

III. Phase A - Eight Motor Program (cont)

B. OVERALL PLAN

1. Approach

The approach to planning the facilities for Phase A is based on several factors which are departures in emphasis from previous 260-SL experience and the Task I single-motor facility modification study. First, the quantity of motors and schedule for processing suggest that facilities capabilities are more likely to be limiting than are component hardware delivery schedules, and that expediencies previously acceptable would be replaced with totally adequate facilities and equipment. Second, the need to demonstrate more stringent performance goals based on flight requirements will increase the attention given to product uniformity, quality, and reliability. Third, each operation must be coordinated with other operations on other motors being processed at the same time in order to minimize both the quantity of facilities and the peak manpower requirements.

In the processing and static testing of 260-in.(6.6 m)-dia motors, the most important (and most expensive) facility is the cast-cure-test (CCT) caisson. Most of the processing and test operations are either performed at that location or directly support operations there. Therefore, in assessing the schedule for Phase A, consideration was given to the need for an additional CCT facility. Processing and static testing of each motor is estimated to require approximately five months at five days per week and slightly more than four months at seven days per week, even without consideration of case rehabilitation and hydrotest requirements. Obviously, to meet the requirement for eight motors in 30 months, a second caisson would be required. Requirements for this caisson are discussed in a later section.

An overall schedule, in the form of a motor flow chart for each caisson and the insulation facility, as shown in Figure 2, was developed on the

III.B. Overall Plan (cont)

basis of estimated times for each process operation and certain non-interference requirements. Non-interference refers to elimination of like operations at each caisson, static test firing during casting operations at the other caisson, and case insulation during a casting operation. It was determined that, with slight improvements in the exisiting propellant production rate capabilities, all other operations could be suspended during motor casting. This had the advantage of limiting the maximum work force to that required for propellant processing and casting, which is the phase requiring the largest work force. Consequently, the facility schedule shown in Figure 2 has seven interruptions corresponding to casting operations at the other CCT. It also can be seen that delivery of the third and fourth motor cases is not pacing, and that the total time required is two months less than the target processing time span of 2.5 years.

2. Location of Facilities

a. Cast-Cure-Test Caisson

Location of the new CCT caisson was evaluated on the basis of minimum overall cost, distance from the instrumentation center, explosive hazard separation distance, and relationship to future requirements.

(1) Explosive Hazard Separation Distance

Location of the second CCT facility and a new insulation facility are dependent to a significant degree upon explosives criteria for separation. Using Reference (a), the Kennedy Space Center Explosives Safety Handbook, as a source, separation distances for each facility were evaluated.

Reference (a): John F. Kennedy Space Center Explosives Study Handbook GP-469, dated 1 July 1968.

III.B. Overall Plan (cont)

In selecting criteria for separation, the quantity and characteristics of the hazardous material, as well as the degree of acceptable damage, and protection available, must be determined. The quantity of solid propellant is the 3,400,000 lb (1,542,000 kg) required to load a single motor. In normal use, the typical composite solid propellant usually is considered to be in Class 2, or non-detonating, indicating the hazard is deflagration. If the adjacent materials or facilities being considered for separation are otherwise unprotected, the minimum spearation distance would be 1,800 feet (549 m), as indicated in Table 4-23 of Reference (a).

The detonation hazard of composite solid propellants is not well defined, particularly for very large quantities. Although this class of propellant normally is not considered detonable, detonations can be achieved if a large enough quantity of donor explosive is available. For example, if the solid motor is used on a missile or space vehicle in combination with a Class 7 solid propellant or a liquid rocket propulsion system, the detonation hazard clearly would be increased. Secondarily, even if the detonation hazard exists, the detonation yield of the propellant is not well established, but TNT equivalencies ranging from 5% for storage to 50% for launch typically are assumed. For this study, yields of 5% for processing and storage, and 10% for static testing were assumed. These figures are conservative, since the caisson would concentrate any overpressure in the vertical direction, thus mitigating near-surface effects.

For the intraline safety criteria, or the distance at which the blast would not propagate, the minimum separation would be 1,200 feet (366 m) for 10% TNT equivalence for unbarricaded storage. For inhabited building safety, the required minimum separation would be 3,930 feet (1,200 m) for 5% equivalence and 4,780 feet (1,460 m) for 10% equivalence. These distances were taken from Reference (a), Table 4-16 and 4-17 for Class 7 explosives.

III.B. Overall Plan (cont)

Therefore, the minimum separation distance between CCT facilities for Phase A, where static testing is required, can be interpreted to be the 1,800 feet (549 m) for Class 2 separation, or the intraline criteria for 10% TNT equivalence of 1,200 feet (366 m). The greater distance of 1,800 feet (549 m) was selected for use here.

The minimum separation distance for an insulation facility (contemplated for a site between the CCT area and Canal C-111) would be based conservatively on criteria for inhabited buildings, since the cost of construction and operation of the facility is essentially insensitive to variations in separation distance along the case receiving route. As discussed in a later section of this report, the facility would not be justified for Phase A, but would be required for Phase B. Since there are not static test firings included in Phase B, the 5% TNT equivalence for storage and processing would be applied, resulting in a minimum separation distance of 3,930 feet (1,200 m) from either CCT.

(2) Location of Second CCT Facility

In developing a facilities plan, the location of new facilities is a significant factor in function as well as cost. Placement of the second CCT, which will be the most expensive facility addition, is affected by several considerations since it is multifunctional in concept.

The safety considerations described in the previous paragraphs require a minimum separation from the existing CCT of 1,800 feet (55 m). Additionally, the separation from the test control room of 2,700 feet was maintained.

To utilize both the existing Propellant Pot Preparation (PPP) Building and to be adjacent to access roads, the second CCT was

III.B. Overall Plan (cont)

located east of the existing CCT along the planned road from Canal C-111, as shown in Figure 3. However, perhaps the most compelling reason for selecting that site was the Phase B plan, which will require access to the casting facilities by the canal. While the Phase A ground rules do not include this factor, the long-term needs realistically would have to be evaluated, where no significant cost penalty is incurred. For Phase B, the CCT facility costs are more sensitive to canal distance than to utilities, roads, and other distance-related factors. The principal disadvantage of the selected location is that potential loss of instrumentation signal strength for static testing due to cable length. This aspect was resolved and is discussed in a later section.

C. CASE HANDLING

1. Previous Experience

The short-length motor cases were delivered previously on a strong-back transporter, which was shipped by barge from the case fabrication site to the Homestead Bay Front Park, where it was off-loaded. Movement to the DCP plant was accomplished by handling over public roads. On-plant movement was similar. Lifting of the cases for installation and removal at the CCT caisson required a 300-ton (272,000 kg) stiff-leg derrick installed on-site and two portable cranes.

As described in the Task I report, the full-length case would be moved in a similar manner, except that the highway route would be unfeasible. Consequently, the Task I approach was to provide a graded road from an on-plant location on the C-111 canal to the CCT facility. In addition, the stiff-leg derrick would be extended.

III.C. Case Handling (cont)

2. Process Requirements

Requirements for handling the Phase A motor cases are no different from those existing in the Task I study, except that the quantity of cases and on-plant moves would be greater, and the additional CCT must be considered.

3. Facilities Selection

The receiving and on-plant case moving functions can be accomplished with the same transporter and over the same route as selected for the Task I single-motor program. Consideration was given to the need for a second transporter which was deemed unnecessary for the following reasons.

— The transporter would have to be returned to the case fabrication plant three times. With two transporters, two of these returns would be required anyway, thus saving the cost of only one trip (approximately $14,000). An additional transporter would be expected to cost approximately $120,000.

— Only one month is scheduled for the transporter return and delivery of the third case. This is a marginal schedule, but there is a two-week dead period between the scheduled receiving date and the need date for insulation, waiting for availability of CCT No. 1, which could be used for case delivery. Additionally, this situation occurs, only once on the schedule.

— On two occasions fired cases must be removed from the caisson while the transporter is being used to deliver an insulated case to the caisson for loading. While it would be convenient to have a second transporter for direct placement of the fired case, an intermediate position can be employed without significant expenditure, schedule penalty, or interference with installation of the insulated case.

III.C. Case Handling (cont)

The graded road and receiving dock selected for Task I facilities ostensibly would be adequate for the Phase A needs, except that the maintenance under seasonal precipitation conditions and uncertainty of the load-carrying capacity of the unsurfaced road would justify improvement of the road surface. Construction of a 2-in.(5 cm)-thick asphaltic concrete surface and upgrading of the receiving dock is estimated to cost $120,000.

Because the case weight and length are the same as defined in Task I, the extended stiff-leg crane would be adequate for use at CCT No. 1. An identical crane would be needed at CCT No. 2, at an estimated cost of $592,000.

D. CASE INSULATION

1. Existing Facility

As a result of the single-motor processing study, several facility modifications and additions were identified, and therefore become the existing facility for the eight-motor processing study. The Task I single-motor facility additions and modifications for case insulation operations are summarized as follows:

— Extend the paved area on the south side of the General Processing (GP) building to provide an adequate surface for maneuvering the transporter and chamber.

— Construct a new building on the south side of the G.P. building, similar to that used for 260-SL motor processing, to enclose the case during insulation processing operations.

— Provide a heating and distribution system for the new enclosure.

III.D. Case Insulation (cont)

— Raise the case access frame and platform on the southeast wall of the G.P. building to accommodate the higher 260-FL case centerline.

— Remove the existing roll-up door in the northeast corner of the G.P. building and install a 28-ft (8.5 m) high hinged door.

— Install new monorail system and support structure to accommodate the higher loads anticipated during 260-FL motor processing.

The general sequence of operations envisioned for installation of the IBT-100/IBT-106 insulation system into the motor case is described as follows:

— Move the motor case into insulation processing facility at the General Processing building.

— Install lighting and equipment truss.

— Install environmental control equipment and utilities.

— Vacuum gritblast, clean, and prime case interior.

— Process and install forward dome and sidewall insulation.

— Cure forward dome and sidewall insulation at ambient temperature for 24 hr, then at 135°F (57°C) for 48 hr.

— Install aft dome insulation.

— Cure aft dome insulation at ambient temperature for 24 hr, then at 134°F (57°C) for 48 hr.

III.D. Case Insulation (cont)

— Apply silicone release to forward and aft dome insulation surface.

— Install forward and aft propellant boots.

— Cure propellant boots at ambient temperature for 24 hr, then at 135°F (57°C) for 48 hr.

— Install aft boot extension.

— Complete NDT inspection.

— Complete all repairs as necessary.

— Remove environmental control equipment and lighting/equipment truss.

— Install environmental covers.

— Move case to CCT facility for propellant loading.

The 260-FL motor insulation system design used for the eight-motor program facility study is reported in NASA CR-72584*. Requirements for the IBT-100/IBT-106 trowelable materials are summarized in Figure 4, and are based on a 15% loss factor and 3,000 lb (1,361 kg) maximum batch size.

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* NASA-LeRC Report NASA-CR-72584, "Development of Cost-Optimized Insulation System for Use in Large Solid Rocket Motors," Vol. IV: "Task IV - 260-In.-Dia Motor Insulation System Design and Process Plan," Contract NAS3-11224, dated August 1969.

III.D. Case Insulation (cont)

2. Specific Process Requirements

Four of the eight motors in this program phase will be processed with rehabilitation of previously fired chambers. Consequently, post-test chamber rehabilitation operations must be included in the process plan for these four motors. The process plan for the four motors using new chambers will be the same as that derived for the single-motor program.

3. Process Facility Options

Only two insulation facility options are readily apparent:

Option 1: use the "existing" facility at the G.P. building.

Option 2: construct a new insulation facility along the case receiving route between the C-111 canal and the CCT area.

For this program phase, the selection of Option 1 is clear cut. The trade-off costs involved here are incurred either in the movement of chambers from the unloading dock (or CCT) to the G. P. building and return, or in the construction of a new facility. The estimated cost of sixteen in-plant chamber movements is $115,000, as compared to a new facility construction cost of $838,000 (see Section IV.D.). Insulation facility Option 1 is selected because of the significant cost differential and there are no critical schedule interfaces that would necessitate either new or dual facilities.

4. Selected Facilities and Process Plan

a. Facility

The "existing" facilities and equipment as previously described (Section III.D.1) are suitable for the 8-motor progran. Since the

III.D. Case Insulation (cont)

environmental enclosure is a wood structure, it is assumed that adequate maintenance will provide the necessary use life. Therefore, no new facilities or equipment are planned.

b. Process Plan

The sequence of operations previously described for installation of the IBT-100/IBT-106 insulation system is applicable to the four motors in this program phase which require new chambers. However, some modifications to this process plan are necessary to rehabilitate and reinsulate the four fired chambers.

To rehabilitate the fired chambers, sidewall insulation must be removed; exposed metal surfaces must be cleaned and primed; and forward and aft dome insulation must be abraded or vacuum-blasted to expose virgin material. These operations can be accomplished in the CCT facilty.

Three methods of sidewall insulation material removal were considered: chemical, thermal, and mechanical. Chemical methods would be virtually impossible to apply with the chamber in a vertical attitude, and would require elaborate precautions to protect the dome insulation. For these reasons chemical removal methods were rejected. Tensile and shear bond strength tests show that the IBT insulation-to-primer-to-steel bond strength is not reduced significantly at temperatures below 350°F (177°C). Thus, the equipment required to obtain localized temperatures of 350 to 400°F (177 to 204°C) at the sidewall renders the thermal removal method impractical. Vacuum-gritblasting appears to be an economical and feasible method of sidewall insulation removal.

After test firing, the four chambers to be rehabilitated will be processed as follows:

— Scrape and wash the insulation to remove loose char.

III.D. Case Insulation (cont)

— Vacuum gritblast the forward and aft dome insulation until virgin material is exposed.

— Vacuum gritblast sidewall until bare metal is exposed.

— Remove residual material from gritblasting operation.

— Clean all exposed surface.

— Apply primer to sidewall and cure as required.

— Conduct hydrostatic proof test.

— Remove chamber from CCT and move to the insulation processing area.

— Dry the chamber interior at 135°F (57°C) for 24 hr.

— Continue insulation processing operations.

Insulation processing operations for rehabilitated chambers following the hydrostatic test drying cycle will be the same as those previously described, with the exception that the forward and aft dome insulation will be restored to original contour by applying uncured IBT to the residual virgin material remaining in the chamber.

III. Phase A - 8 Motor Program (cont)

E. PROPELLANT PROCESSING AND CASTING

1. Raw Materials Storage and Handling

Raw material storage facility requirements were examined on the basis of one lot combination per motor. It is planned that lot qualifications can be initiated 30 days prior to each motor casting. On the basis of the eight motor program casting schedule, storage facilities for only one lot combination are required. The schedule allows a period of at least 30 days between completion of cast of a motor and initiation of lot qualification for a subsequent motor. The results of this study are summarized in Figure 5. Major changes are recommended for the storage of ammonium perchlorate, aluminum, PBAN and DOA.

a. PBAN and DOA Storage

The merits of storing PBAN and DOA in tank cars and blend tanks were compared. Blend tanks appear to have quality and raw material cost advantages. Maintenance of seals on tank cars has been a problem in the past.

Contingency material must be provided for each lot combination. With blend storage tanks, any contingency or residual material left in the tank can be blended with the subsequent lot. Thus, only one contingency quantity is required for the entire program. To avoid loss of the contingency material using tank car storage, the material would have to be returned to the manufacturer for blending with a subsequent lot. To accommodate the schedule for use and material manufacturer, two contingency quantities would have to be provided, i.e., the turn-around time for the contingency material would be too great to permit blending of the material with the lot immediately following.

III.E. Propellant Processing and Casting (cont)

Therefore it would have to be blended with the second lot following. It is apparent that this approach has quality implications due to difficulties in controlling the storage environment and in maintaining material purity and lot identification when using tank cars.

On the basis of these considerations it was concluded that blend tanks for PBAN and DOA should be installed. Tank sizes and costs were defined and are presented in Figures 6 and 7. A 50,000 gallon (189 m^3) stainless steel tank equipped with a heat exchanger and agitator will be required for PBAN and a 20,000 gallon (76 m^3) stainless steel tank will be required for DOA, at a total cost of $111,500.

b. Oxidizer Tote Bin Requirements

Shipment and storage of the 2.547 million lb (1,160,000 Kg) of unground oxidizer required to cast each motor will require 425 Tote bins with a capacity of 6000-lb (2720 Kg) each of unground oxidizer. Tote bins with a 90-ft^3 (2.6 m^3) capacity rather than a 74 ft^3 (2.1 m^3) of oxidizer (5 days pre-grinding) will empty 115 of these Tote bins, but dispensing the blended oxidizer to the batch weight of 4140 lb (1880 Kg) for propellant batch weight of 6000 lb (2720 Kg) will require 166 Tote bins, or 51 more than were emptied. Allowing five additional Tote bins to facilitate transfer and for contingency, a total of 431 + 51 + 5 = 487 Tote bins is required to process each full-length motor.

For the Phase A program, the maximum rate schedule indicates that the minimum casting process cycle (time between the start of casting of consecutive motors) is 75 days between the fourth and fifth motors. Using a new lot of raw materials for each motor, utilization of the Tote bins can be summarized as follows:

III.E. Propellant Processing and Casting (cont)

	Estimated Span Time, days
Motor Cast	17
Lot Qualification	21
Shipment (7 days each way)	14
Oxidizer Pregrind	1
	53

This leaves 22 days for the vendor to manufacture and cross-blend the oxidizer lot and load the Tote bins for return shipment. This schedule should be adequate, so that a single set of bins will meet program requirements for Phase A.

The estimated cost of 487 Tote bins is $292,200.

c. Unground Oxidizer Storage

For the ammonium perchlorate it is recommended that a weather tight structure be provided for storage. Previous practice was to store Tote bins containing ammonium perchlorate on an unsheltered pad. Polyethylene covers were placed over the bins to reduce the collection of water on the bin top. In the 260-SL experience, oxidizer was lost due to leakage of the Tote bins. To minimize material loss and assure quality it is proposed that a weather tight storage structure for oxidizer be provided.

Safety considerations require that this structure be used only for oxidizer storage. Its size must be sufficient for the nearly 500 Tote bins of oxidizer required for each motor. Assuming that the bins will be stacked two high, and allowing 50% in floor space for access and aisles, it is estimated that a 7,000 ft^2 (650 m^2) floor area will be required. Temperature and humidity control of the building environment would not be required. Figure 3 shows two storage buildings on the existing storage pads. The estimated cost of this facility is $89,500.

III.E. Propellant Processing and Casting (cont)

d. Aluminum Storage

A weather tight storage facility must also be provided for aluminum powder. All other materials except oxidizer could also be stored in this structure. Material losses due to drum corrosion and leakage have been experienced when drums of aluminum powder were stored in an unprotected area. For 260-SL motors, the drums of aluminum powder were stored in the fuel building and in the Homestead warehouse. These storage areas are not large enough to accommodate the quantities of materials required for full length motors. In addition, as discussed in a later section, Tote bins would be used in place of drums to improve the premix preparation process. Therefore, a warehouse-type storage building of 40 by 50 ft (12 by 15 m) dimensions would be provided to store approximately 95 Tote bins, stacked two high. The building would be located adjacent to the Fuel Preparation Building, as shown in Figure 3, and is estimated to cost $41,700. The cost of the 90 ft^3 (2.6 m^3) Tote bins is estimated to be $57,000.

2. Fuel Preparation

a. Premix Materials Handling

The various materials which make up the fuel premix were examined for optimum handling methods, and are summarized in Figure 8. Because of the modifications outlined in Task I, the only additional improvement suggested is for the dispensing of aluminum powder.

The premix processing step which primarily determines the length of the batch preparation cycle is the addition of the aluminum powder to the make-up tank. Approximately 10 drums of aluminum are required for each

III.E. Propellant Processing and Casting (cont)

batch of premix and the method of addition involves installing a special funnel and valve on the drum, inverting it with a hoist, and feeding the powder to the tank through a Syntron feeder.

This method is relatively slow and presents a great deal of inconvenience in building operation. A faster and more efficient approach, aluminum powder in bulk containers, such as Tote bins. With this method, the aluminum could be pre-weighed in the bins and dispensed at a much higher rate into the premix. In addition, the number of operations during fuel preparation which are subject to human error would be reduced substantially.

As discussed previously, the aluminum would be stored in a separate building. The aluminum would be dispensed into Tote bins by the supplier and weighed at DCP to adjust the bin content to the required amount for a premix batch, approximately 6,000 lb (2,720 Kg). During premix preparation weighing would not be necessary. The bins would be raised by a new hoist to the second floor of the building (as were the drums) and installed on a tilting fixture. The aluminum would be dumped into a feed screw and Sweco screen for dispensing into the premix. The estimated cost of modifications to accept the Tote bins is $30,600.

b. Premix Dispensing

Dispensing of premix into the vertical mix bowls for 260-SL-1, -2, and -3 was done with a precision positive-displacement pump. The amount of premix dispensed was determined by counting the revolutions of the pump and when the required number was reached, valves were actuated which diverted the pump output to recirculation. Prior to the propellant production run for motor, the pump was calibrated to determine the correct number of pump revolutions by dispensing premix into drums and weighing the amount dispensed.

III.E. Propellant Processing and Casting (cont)

Some difficulty was experienced with the electronic counters on Motors 260-SL-1, and -2, but the current premix metering system is equipped with two independent counters to record the number of pump revolutions and actuate the divert valves. This redundancy has afforded a high degree of system reliability and there was no evidence of incorrect premix dispensing for batches prepared for 260-SL-3. The amount of premix delivered by a single revolution of the pump is small and if the pump and counters are functioning properly the system is extremely accurate. However, precise control of the quantity of premix displaced into the bowl is necessary to achieve control of the propellant properties, and the counters provide only an indirect measure of the quantity of premix delivered. Since the pump is essentially a constant-volume device, it is inherently subject to the following errors:

- Normal density variations in the premix will affect the weight of premix delivered.

- Cavitation of the pump (caused by a partially plugged screen for example) will result in an incorrect delivered weight due to entrapment of gas in the stream.

- Variations in temperature of the premix will cause variations in premix density and consequent variations in delivered weight.

Two techniques have been considered for providing an independent check on the amount of premix dispensed into the bowl, i.e., a recording flowmeter on the discharge side of the metering pump and a weigh tank to provide direct measurement of the weight of premix discharged. The first of these alternatives was selected for the Task I program and is subject to exactly the same sources of error as the present system, therefore providing additional redundancy to proper functioning of the counters. Furthermore, the

III.E. Propellant Processing and Casting (cont)

additional electronic components (flowmeter, transmitter, digital recorder) represent another source of potential malfunctions which could increase scrap rate (without affecting product reliability).

The second alternative, a separate weigh tank, has the significant advantage of providing a direct measurement of the weight of premix transferred into mix bowl which is, ultimately, the property which most needs to be carefully controlled in order to minimize propellant property variability. Use of a separate weigh tank for premix dispensing would potentially reduce scrap losses and would provide additional surge capacity for the system. The estimated cost of a weigh tank and associated equipment is $27,000. The cost of the weigh tank would be justified by improved reliability and partially offset by decreased scrap potential.

3. Oxidizer Preparation

a. Facility Capability

The existing oxidizer grind station would be modified under the plan derived for Task I by replacing the High Speed MikroPulverizer (HSMP) system with an additional MikroAtomizer (MA) system, yielding a total of one Slow Speed MikroPulverizer (SSMP) system and two MA systems. This modification would be adequate to provide an estimated sustained output of 5,350 lb/hr (2,430 Kg/hr) of 70/30 SSMP/MA blend ratio and 5,780 lb/hr (2,620 Kg/hr) of 65/35 blend ratio, or very close to the requirements for supporting the estimated propellant mix capacity. Improvements in the propellant mix capacity of the existing facilities could be supported by producing a supply of blended oxidizer prior to the start of propellant production.

III.E. Propellant Processing and Casting (cont)

b. Oxidizer In-Process Storage

Transfer and handling of the Tote bins loaded with ground and blended oxidizer for the vertical mix stations and the continuous mixer would be greatly facilitated by a centrally located in-process storage facility. The facility would be sized to contain the 56 Tote bins required for Phase B to accommodate the additional volume of ground and blender oxidizer during the 5-day pre-grind period prior to each propellant production run. If the bins were stored stacked two high and allowing 100% excess for aisles and access areas, the required storage area is approximately 1100 square feet (102 m^2). This storage building would need to be weather-tight but not humidity controlled. The 30 by 40 ft (9.2 by 12.2 m) building would be located as shown in Figure 3 and would cost an estimated $28,400.

4. Propellant Mixing

a. Vertical Batch Mixers

The vertical batch mixing facilities and procedures were evaluated to determine the changes necessary for acceptable quality and efficiency of operations. The principal elements of the vertical batch process are oxidizer addition and the actual mixing step.

Oxidizer addition time has been observed to be a major variable in the total batch mix cycle. Factors influencing the addition time include the Tote bin vibration system, oxidizer age and oxidizer blend. Evidence of the importance of an adequate vibration system is offered by data obtained during the propellant processing for Motor 260-SL-3. For example, there was a 7-minute difference in oxidizer addition ties between the North and South vertical mix stations. This difference can be attributed to a superior system in the North station.

III.E. Propellant Processing and Casting (cont)

Analysis of oxidizer addition data from the 260-SL-3 and -3 motor runs provides a basis for assessing the effect of oxidizer blend (70/30 SSMP/MA for 260-SL-2 vs 65/35 - 70/30 SSMP/MA for 260-SL-3) and the adequacy of the addition system. This analysis, presented in Figure 9, shows that oxidizer addition for 88% of the batches processed for 260-SL-2 was completed in 39 minutes or less compared to only 80% of the SL-3 batches containing the finer blend. Surprisingly, only 10% of the SL-3 and 6% of the SL-2 batches required longer than 49 minutes. The shape of these time distribution curves indicate that the basic addition system is adequate. Improvement of the vibration system will serve to reduce the time distributions. Improvement in addition times will also result from the installation of nitrogen jets in the oxidizer chute and the better control storage time for blended oxidizer made possible by the increased capacity planned for the oxidizer facility. The nitrogen jets will prevent oxidizer hang-up in the chute and reduce the batch cycle time. A 30-min oxidizer addition time for a 65/35 SSMP/MA blend appears to be conservative value obtainable with these system modifications.

Several modifications to the vertical batch mixer and mixing procedures are planned. These include an improved vacuum system (included in the Task I facility modifications) an increase in batch size to 6000-lb (2,720 Kg), alteration of the mix procedure, and installation of nitrogen jets in the oxidizer chute, as mentioned above.

The batch size increase was considered under Task I, but was discarded on the basis that it was an unnecessary change, requiring a demonstration of feasibility and an increase in oxidizer Tote bin size. For this program, which has a defined schedule objective, the opportunity for demonstration would be greater, and a new lot of Tote bins would be required anyway. In addition, the increase in unit cost would be more than offset by the greater capacity of each bin.

III.E. Propellant Processing and Casting (cont)

The procedural change would eliminate the initial vacuum check before oxidizer addition and combine this function with the new 10-minute vacuum mix period after oxidizer addition, but before final fuel (curing agent) addition.

A 15- to 27-minute decrease in the 147-minute total batch cycle time experienced during 260-SL-3 is the estimated results from the proposed modifications. The breakdown of estimated time reduction is:

Oxidizer addition	5 to 10 min
Vacuum check	5 to 7 min
Clean out of Oxidizer Chute	5 to 10 min
Total	15 to 27 min

With a 132-minute batch cycle time (147 minus 15) and 6,000-lb (2,720 Kg) batches an average production rate of 2,730 lb/hr (1,240 Kg/hr) from each mixer is estimated.

b. Continuous Mixer

Performance of the continuous mixer was evaluated for potential changes for an improved level of operational reliability. The major elements in the continuous mix system which require modification are indicated clearly by an analysis of the down times experienced during the processing of 260-SL-2.

	% of Total Down Time
Oxidizer fluidizer	65.8
Oxidizer conveyors	8.6
Oxidizer belt feeder	19.6
Motor feed	2.2
Other	3.3
Scheduled maintenance, etc	0.5
	100.0

III.E. Propellant Processing and Casting (cont)

As shown, the oxidizer system accounted for 94% of the total down times. The modifications necessary for significant improvement consist primarily of increasing the capacity of the oxidizer system. The cost of modifications has been estimated from $150,000 to $750,000, depending on the assumption made. A rigorous evaluation of possible modifications and corresponding quantitative benefits was not within the scope of this program. Accordingly, since the system has been demonstrated to be successful and comparable in operating cost to the batch mixers, no modifications are recommended.

c. Propellant Production Rate

The production rate capability of the propellant processing facilities is tied to the mixing rate. In most systems, the maximum rate depends on a key element and, if efficiently designed, the key element is the most expensive of those which influence the rate. Accordingly, the mixing process is used as the limiting element, and other processes, from component preparation through casting, necessarily must be capable of supporting at least the maximum mix rate.

Criteria for minimum cast rates were determined in the Processing Guidelines established under Contract NAS3-12002, which correspond to the production rate available with two vertical batch mixers. On the other hand, it was shown also that propellant grain quality could be expected to be improved with higher cast rates and without delays during casting.

Based on the mix rates estimated previously, the following motor cast times were calculated for these combinations of existing mix facilities.

III.E. Propellant Processing and Casting (cont)

Mixers	Production Rate, lb/hr (Kg/hr)	Time to Cast Motor, days
2 VBM + CM	8,780 (3,980)	17.3
2 VBM	5,460 (2,480)	27.8
CM + 1 VBM	6,050 (2,740)	25.2

Consideration was given to the possible loss of the use of a mix station. Of all the propellant processes, the mixing process is the most likely to be subject to catastrophic failure. While safety records are generally excellent, this possibility must be considered in the assessment of production capacity and backup capability. The schedule for the 8-motor program appears to have adequate flexibility to compensate for a lower mix rate for an extended period of time, such as the six to ten months that might be required for repair and reconstruction of a damaged mix station. On this basis, no need is seen for additional mix capacity.

5. Cured Propellant Samples

a. Carton Cure and Storage Oven Requirements

It is expected that carton samples would be obtained at the rate of two cartons for each vertical mix batch and four cartons for each continuous mix pot. Assuming 6,000 lb (2,720 Kg) for each batch on a batch cycle of 2.25 hours for both vertical mixers and 7,500 lb (3,400 Kg) for each CM pot at an average production rate of 3,320 lb/hr (1,500 Kg/hr), a total of 374 VBM batches and 186 CM pots (including losses) would be required to cast each motor. A corresponding total of 1,492 carton samples would be obtained. In addition, six additional carton samples would be obtained from every sixth CM and BVM pot for longer-term and specialized tests, resulting in 544 more cartons, or a total of 2,036 cartons per motor. For this program phase, there

III.E. Propellant Processing and Casting (cont)

is not expected to be a significant quantity of residual samples from preceding motors or materials lost qualification requiring storage at the time of a motor casting. Neither is there any allowance made for casting burning rate and specific impulse test motors, since there is no apparent need for these on a routine basis.

The existing curing oven at the Qualification Motor Processing (QMP) building contains 36 lineal feet (11.0 m) of six-high shelving 18 inches (46 cm) deep with an estimated capacity of 1,386 cartons. The addition of free-standing shelving, as recommended in the Task I report, would double this capacity to 2,772 cartons, which would be entirely adequate for this program phase.

b. Mechanical Property Test Specimen Preparation

All propellant mechanical property testing conducted in the past at DCP has utilized Instron bar specimens prepared by die cutting slabs of propellant sawn from the sample cartons. Test results have shown that a milling slitting technique provides higher quality and more uniform specimens. The mechanical properties are less variable and more reliable than those obtained from die cut specimens. Milled specimens are now in standard use, and this technique is recommended for adoption at DCD. The procedure for preparation of a milled Instron bar is basically as follows:

(1) The carton is cut into 1-inch (2.5 cm) thick slabs on an automated arbor saw (Bartley-Lucas or equivalent).

(2) The slabs are milled into the profile of a standard ICRPG Instron bar using a profile mill (another function of the same Bartley-Lucas machine).

III.E. Propellant Processing and Casting (cont)

(3) The milled slab is slit into Instron bars on a gag slitter.

The estimated cost of the machines required to perform the above operations is $15,000 for the mill and $10,000 for the slitter. An additional 150 ft^2 (14 m^2) of enclosed working area adjacent to the Sample Preparation building will be required to accommodate this equipment. The addition is estimated to cost $6,000.

c. Mechanical Properties Testing

In order to minimize the effects of temperature on the measured propellant mechanical properties, the Instron bars are conditioned at a constant temperature of 77°F (25°C) for a minimum of one hour prior to testing. In order to have adequate space for conditioning of the bars, it will be necessary to add a room of approximately 100 ft^2 (9.3 m^2) to the existing Quality Control Laboratory, at an estimated cost of $4,000.

The testing capability of the Instron tester currently at DCP is approximately 100 specimens per eight hour shift. Using the sampling plan described previously, the current facilities are adequate for program needs, if operated on a two shift basis.

6. <u>Cast and Cure Operations</u>

a. Existing Facilities

The bayonet casting process was described in the Task I report, in which special requirements for casting were added to assure the integrity of the forward fin area of the grain (see Figure 1). An adjustable

III.E. Propellant Processing and Casting (cont)

12-bayonet casting system was devised to provide simultaneous propellant flow between each fin of the core.

The existing CCT includes a 52.5 ft (16.0 m)-dia by 150 ft (45.8 m)-deep caisson, a movable building, a 190 ft (58 m)-high stiff-leg derrick (used for motor case lifting, core lifting, and handling of tooling), a heating and cooling system, environmental shroud, and a propellant pot preparation building.

b. Special Requirements

(1) Caisson

As mentioned previously, a second Cast-Cure-Test (CCT) facility would be necessary to accommodate the eight-motor program schedule. Because this is such a large cost element, the caisson must have the basic capacity and would be designed to accept the probable configuration for the 30-motor program. That is, the diameter would have to be adequate for the handling rings needed for a loaded motor.

(2) Casting System

The 12-bayonet casting system devised for the Task I requirements was selected on the basis of minimum cost. The multiplicity of certain operations suggests that recurring labor costs and complexity of operations would be inappropriate on a long-term multiple-motor program. A more sophisticated, less complex casting system is desirable. The system should be sufficiently portable to be used at both CCT facilities.

III.E. Propellant Processing and Casting (cont)

(3) Movable Cast Building

The existing cast building is not sufficiently durable or portable for multiple-motor programs. In addition, the building criteria should include the improved casting system and capability for complete motor assembly. A building will be required at each CCT.

(4) Environmental Systems

The environmental systems, including the shroud and adapters, may not provide adequate thermal response for this program schedule. Heating and cooling system components and environmental shroud components may be used for both CCT facilities.

c. Selection of Optimum Facilities

(1) CCT Caisson

The existing caisson was sized for growth potential and is larger than is necessary for the motor configuration considered in this study. For the same vertical location, relative to surface level, the caisson can be approximately 33 feet (10 m) less deep. This reduction in depth not only affects the caisson foundation cost, but also eliminates the need for a thrust spacer. The only penalty is the loss of growth potential for longer versions of the motor.

Sizing the diameter is dependent upon the configuration of the motor handling rings and trunnions, the environmental shroud, and caisson equipment such as the stairway, elevator, and environmental ducting. Although Phase A is to cost-optimize facilities only on the basis of the

III.E. Propellant Processing and Casting (cont)

eight-motor requirement, the potential use of this major facility for a production effort suggests that the Phase B configuration, with the loaded-motor handling rings, should be the limiting size factor. In that instance, the aft flare of the stage, which has a maximum dia of 355 in. (9.02 m), influences the location of the trunnions. The trunnion ends are estimated to include a maximum diameter of approximately 400 in. (10.16 m). Allowing 10 in. (0.25 m) radial clearance for the trunnions and 6 in. (0.15 m) for environmental shroud thickness, the outside diameter of the shroud would be 432 in. (10.97 m). Then, allowing 9 in. (0.23 m) radial clearance to the caisson stairway and 90 in. (2.28 m) for the stairway, the caisson diameter may be calculated to be a minimum of 432 + 18 + 180 = 630 in. (10.97 + 0.46 + 4.57 = 16.0 m), or the same as the existing caisson.

There are approaches to reducing the required caisson diameter. The motor could be eccentrically located, since the staircase is needed only on one side. This would reduce the diameter by 90 in. (2.28 m). The forward trunnions could be removed during case installation, reducing the required shroud diameter by 60 in. (1.52 m), although the upper end of the shroud would have to be slotted to clear the aft trunnions. Reduction of the Phase B shroud diameter also has a distinct advantage in cooling the grain after cure. These two changes would reduce the required diameter to 480 in., or 40 feet (12.2 m) and would appear to be an attractive low-cost approach. The principal disadvantage would be the effect of the eccentric thrust load on the bottom plug of the caisson, but a redesign of the plug-to-caisson joint probably would alleviate this concern. The cost of this smaller caisson is estimated to be $2,004,000 including foundation, elevator, stairway, site preparation, and engineering. The comparable cost if the existing diameter were retained would be $3,233,000.

Another alternative would be to plan on using the caisson wall (insulated) as the environmental shroud. The caisson diameter

III.E. Propellant Processing and Casting (cont)

could be reduced to 432 in. or 36 feet (10.97 m), unless the caisson were slotted at the aft end, in which case, the diameter would be 372 in. or 31 feet (9.45 m). These approaches would necessarily require an 18 ft (5.49 m)-dia parallel auxiliary caisson with a connecting tunnel for the stairway, elevator, and air ducting, which would offset any cost advantage of the smaller size caisson.

(2) Bayonet Casting System

(a) Criteria

- 12 bayonets for fin grain section (one per fin).
- Cast through all 12 fin bayonets simultaneously.
- Cylindrical grain section may be cast like the 260-SL motors.
- Control bayonet tip submergence between 6 and 18-in. (15 and 46 cm) below propellant surface.
- Fin grain length = 281 in. (7.13 m).
- Total grain length = 1,284 in. (32.6 m).
- Three propellant pots to be cast every two hours.
- Maintain casting temperature environment at 135°F.

(b) Concepts

Various propellant casting concepts and techniques for the fin grain section were evaluated as summarized in Figure 10.

III.E. Propellant Processing and Casting (cont)

Initial consideration was given to the fin section because of the more stringent casting criteria. Having established the best method for fin casting, consideration was given for applicability and modification for casting the cylindrical section.

(c) Propellant Distribution

Several distribution methods were considered for transferring the propellant from the propellant pot to the motor chamber.

Propellant may be distributed from one to three propellant pots to a single manifold which supplies twelve bayonets. Casting time is efficiently used since the system is capable of handling one to three pots, resulting in minimum pot turn around time. Pressure balancing between pots may be necessary to flow simultaneously from two or three pots. Sufficient time is available to cast pots individually in sequence. Simultaneous casting through twelve bayonets occurs regardless of the number of pots on station. Disadvantages of the single twelve bayonet manifold is its larger size, complexity and mobility.

The propellant may be distributed simultaneously from three propellant pots, each connected to a manifold which supplies four bayonets. A four-bayonet manifold is smaller and easier to handle and service than a twelve-bayonet manifold. A three-manifold system provides more flexibility in equipment arrangement in the casting facility. The major disadvantage of the three-manifold system is that casting is delayed until the three propel-are on station for simultaneous casting of the fin bayonets. Pot life is effectively shortened if pots are standing by for the remaining pots.

Propellant manifold location was evaluated on the basis of ease of operation, servicing, complexity and cost. The manifold

III.E. Propellant Processing and Casting (cont)

may be located near the pot, within the chamber near the fins or anywhere between these two locations. Locating the manifold near the propellant pot makes it readily accessible for assembly, servicing, facilitates bayonet pigging, and frees the motor chamber of equipment which blocks visual monitoring. However, longer, reinforced and more expensive bayonets are required with the manifold located near the propellant pot. More propellant is necessary to fill the longer bayonets. Also, the longer bayonets will take longer to evacuate and collapse.

Locating the manifold near the fin section (within the chamber) enables the use of short non-reinforced, inexpensive bayonets. A long feed line or lines, circumventing the casting core, would transmit propellant from the pot to the manifold. It may be possible to shorten the feed line at the top rather than cutting the bayonets. The disadvantages of this configuration are the more complex manifold, difficulty in servicing the manifold and bayonets, and visual obstruction of bayonets due to the manifold.

In view of the above considerations, it was concluded that the distribution system should consist of one to three pots feeding a single manifold which supplies 12 bayonets. The manifold should be external to the chamber as near the propellant pots as reasonable.

(d) Bayonet Immersion Adjustment

A cursory evaluation was made of various concepts for adjusting bayonet immersion depth during the casting operations. Qualitative assessment of schedule, complexity, equipment requirements, cost and safety were made in establishing a preliminary design of a selected method. Further in-depth analysis would be required to establish accurate quantitative ratings and design details.

III.E. Propellant Processing and Casting (cont)

(e) Selected Casting Method

The method selected for bayonet casting consists of horizontally rolling the propellant pots, manifold and bayonets away from the motor chamber, while raising the end of the bayonets the desired distance, as shown in Figure 11. Special flexible bayonet tubes must be designed to negotiate the 90-degree bend from a vertical position in the chamber to a horizontal position along the ground. Special chain, wire, or fiber reinforcement in the bayonets must permit tube bending while providing tube support without stretch. The propellant pots, manifold, and bayonets operate as a unit on a guide-rail or road system. Twenty-five ft of horizontal movement is necessary to adjust bayonet immersion the entire propellant fin length without shortening the bayonets. An electric powered winch system could be used to horizontally pull the entire casting system. The bayonets ride on individual horizontal roller guides between the manifold and the chamber. A circular distribution ring over the chamber aligns the bayonets in the proper position with respect to the chamber and fin section. Another circular distribution ring may be necessary in the chamber above the fin section to provide proper bayonet alignment. This lower ring would slide over the cylindrical core for assembly and disassembly. A horizontal telescoping, or segmented shroud over the bayonets, manifold and lines will be used to circulate air at 135°F (57°C).

The selected casting system permits fast, efficient and safe operation. Bayonet immersion is controlled accurately and easily without shortening (cutting) the bayonets. Propellant pot lifting is minimal, limited to transfer onto and off the winch system track or roadway. Propellant cast time and pot turn around time can be held easily within the required three pots every two hours. Although a complex guide system is required to permit horizontal and vertical bayonet movement and alignment, it

III.E. Propellant Processing and Casting (cont)

is considered within the state-of-the-art and practical costs. The major area requiring further evaluation is the bayonet tube design, fabrication and cost. Such a tube design is considered feasible, however, tube costs are expected to be higher than existing non-flexible designs. The cost of the complete system is estimated to be approximately $175,000.

(f) Alternate Methods for Immersion Adjustment

Adjustment of bayonet immersion depth could be accomplished by cutting, similar to the procedure used on 260-SL-2 and -3. This method requires a relatively simple casting facility and associated low initial cost. Although this method provided a simple, safe and inexpensive casting procedure for the 260-SL motors, it is not applicable for the longer, more complex 260-FL motor, and the more stringent immersion criteria. Considerable handling and bayonet cutting would be required such that the casting rate would be less than the propellant production rate.

Adjustable bayonet stands and tube spacers (spools) were considered, similar to the method selected for the one motor program (Task I). The many operations required by this method cannot be accomplished within the tighter schedule of the 30-motor production program. Additionally, the method involves a rather complex casting setup, including an elevated casting stand above the motor for use of the spacers and bayonet stands.

Bayonet immersion also could be accomplished by vertically lifting entire pot manifold and bayonet system. The casting stand would be raised and lowered with hydraulic hoists similar to an automobile lift. Telescoping columns would be used for platform support as a safety in case of leakage or failure of the hydraulic system. The casting

III.E. Propellant Processing and Casting (cont)

stand size would be similar to that used for 260-SL motors such that pot transfer is accomplished to the side rather than over the motor. This method has the advantages of readily adjusting bayonet immersion without cutting, does not require bending the bayonets or feed lines and can use bayonets similar to that used for the 260-SL motors. However, the elevator casting stand is complex and expensive and pot transfer must be made at various heights. This increases the risks of accident and associated hazards. An elevator could be installed for personnel and pot transfer. The many advantages of this concept warrant future consideration as an alternative method.

A variation of the previous concept would be to evaluate vertically the manifold and bayonets but leave the propellant pot on the ground. A long flexible feed line would supply propellant from the pot to the manifold. This method has the advantages of the preceding vertical lift concept but reduces the hazards of pot transfer and reduces the vertical lift load and size. A hydraulic or screw lift device is still required to raise the manifold and bayonets. Additional ducting is required to supply propellant from the pot to the manifold and to provide the proper thermal environment. The elevated manifold and ducting system would not be readily assessible for servicing and may be somewhat hazardous.

(g) Cylindrical Grain Casting

Casting requirements of the cylindrical grain section are less stringent in that as few as three bayonets may be used. Nevertheless, it is desirable to have maximum utilization of the casting equipment established for the fin grain section. The selected fin casting method is adaptable and desirable for casting the cylindrical section. It is recommended that simultaneous casting occur through three bayonets equally spaced around the core. The remaining nine bayonets will be removed from the manifold and

III.E. Propellant Processing and Casting (cont)

the bayonet ports sealed with closures. The track system for the horizontal movement of the propellant pot, manifold and bayonets will allow bayonet immersion depth adjustment without cutting up to 25 ft (2.6 m). Therefore, cutting of the three bayonets will be necessary at the end of fin casting and at the 50 ft (15.2 m) and 75 ft (22.9 m) levels during the cylindrical section casting. Bayonet cutting will be similar to the procedure used for the 260-SL motors.

(3) Movable Cast Building

The movable cast buildings would be enlarged from the existing size to a 60 ft by 130 ft (18.3 by 39.7 m) floor plan to allow for the improved cast system. The height would be increased by 20 ft (6.1 m) to give more hook height for the bridge crane to allow motor assembly inside the building. The direction of movement at the existing CCT would be south to anticipate the double-boom derrick location of Phase B (see Figure 3). A comparable layout is planned for the second CCT. The buildings would be stiffened to minimize the requirement for diagonal tension rods and would be moved on rails. The estimated total cost of each building, excluding environmental systems, would be $559,000.

(4) Environmental Systems

The requirements for forced air cooling of the propellant grain were reviewed because of the long period of time (14 days) allowed for this operation. (Heating requirements are not a critical element.) The short-length motor grains were cooled from the 135°F (57°C) cure temperature with 60 to 65°F (16 to 18°C) air at a rate of 25,000 cfm (1.18 m^3/s) for 340 hours prior to core removal. These conditions were established on the basis of the minimum motor design temperature of 60°F (16°C) and a cutoff

III.E. Propellant Processing and Casting (cont)

time beyond which forced-air cooling was not significantly effective. That is, the propellant specific heat, conductivity and thickness are the limiting factors when the surface temperatures approach the cooling air temperature.

In cooling a full-length motor to the same condition, the amount of heat to be removed is approximately twice that of the short-length motors. This may be accomplished by increasing the air flow capacity, the refrigeration capacity, (or both) or the cooling time. The last option was selected for the Task I program. Increasing the refrigeration alone would induce a greater axial thermal gradient. Increasing the airflow alone would result in higher initial inlet air temperatures.

The influence of the motor environmental system geometry and grain geometry is significant. The larger diameter shroud required to clear the larger handling rings of the full-length motor would reduce the external air velocities for the same flow rate, thus reducing the heat transfer coefficient and initial thermal response rate. Increased air flow or a more closely tailored shroud could be used to maintain the heat transfer rate of the short-length motor. The main portion of the core for the full-length motor has considerably less perimeter than the short-length motor core, thereby reducing the relative internal surface area available for cooling. The 35% thicker web of the full-length motor and the reduced internal perimeter would increase the total cooling time (based on maximum internal temperature), but not the period required to cool the surface to a given temperature, or the time of effective forced air cooling.

The purpose of cooling the grain after cure is to aid core removal by grain shrinkage and to provide propellant mechanical and ballistic properties within the design or normal operating range. Further conditioning to a specified temperature for test demonstration might be

III.E. Propellant Processing and Casting (cont)

required, but for the processing cycles projected for this study, the thermal gradient would be expected to stabilize at a nominal mean to within approximately 5 to 15°F (3 to 9°C) depending on the ambient temperature history. Accordingly, the control of the grain operating temperature is as much as a function of the environmental history after cooling as a function of the initial cooling rate.

There are no established criteria for the amount of cooling for core removal. From analytical data calculated for the 260-SL grains, it is apparent that approximately one-half the heat removal required to cool the grain to a stable nominal operating temperature would be accomplished in about four days, indicating that one-half the total radial displacement would be achieved at that time. Also, 60 to 70% of the grain would be released from the core at four days, increasing to about 90% at fourteen days (340 hours). Removal of the 260-SL core did not induce a high extraction stress level and the measured core temperatures suggest that the degree of cooling was entirely adequate. As a result, it is concluded that the cooling conditions are not critical, either for core removal or for end use, and that cooling equipment similar in capacity to that employed for the 260-SL motors probably would be adequate for the fourteen days allotted in the Phase A and Phase B schedules, but only if the heat transfer conditions are the same. In order to assure the same level of confidence experienced with the 260-SL motors and to allow the use of simplified environmental shrouds, both the refrigeration and air flow requirements will be increased. The increased capacities will be 60% greater rather than 100%, since the internal airflow cannot be increased effectively.

For the existing CCT the environmental system would be supplemented with a parallel system. New ducting would be installed to the -105 ft (-32 m) level. The estimated cost is $96,800. For the new CCT, the estimated cost of the environmental system is $240,000.

III.E. Propellant Processing and Casting (cont)

The environmental shroud provided in Task I would be adequate for Phase A, and would be utilized at both CCT facilities within the proposed schedule.

7. Summary of Facility Costs

Raw Materials Storage and Handling	$ 591,900
Premix Preparation and Dispensing	57,600
Oxidizer Processing	28,400
Propellant Sample Preparation	35,000
Cast and Cure Operations	3,633,800
	$4,346,700

III. Phase A - 8 Motor Program (cont)

F. STATIC TESTING

1. Approach

To enable definition and costing of the facilities and equipment required to conduct the eight motor test program (Phase A), the operational analyses conducted during the Task I study were extended to include the effects of the essentially uninterrupted 24 month test program, the additional scope of the TVC checkout, hydrostatic proof-testing, and multi-test facility operation. Several basic ground rules and assumptions were applied which influenced the approach used in these studies and the conclusions reached as to program requirements. These are summarized in the subsequent section.

The contractual requirement to define, at the minimum cost per motor, the optimum facilities and equipment needed provides definite guidance in the selection of the facilities and equipment, while still permitting latitude in the quality and magnitude of the items proposed. For example, it would be false economy to select low cost instrumentation systems which may require constant maintenance or compromise test objectives with faulty operation. The few motor tests allowable, and the high cost of each, precludes the loss of data or the malfunction of any test equipment or systems.

Also influencing the selection of facilities and services is the magnitude of the operation in the casting and test area (Area 21). Crews would probably be working at both CCT's, the nozzle/TVC assembly building and the control room area simultaneously. The previous practice (260-SL motor program) of depending on services at the General Processing Building or off-plant whenever a special tool or piece of equipment is needed is not acceptable. The dependence on the Sacramento facility for all instrumentation support would, by necessity, be lessened. The philosophy emphasized in this study promotes

III.F. Static Testing (cont)

self-sufficiency, the use of first-class equipment and providing the support capability in all areas necessary to accomplish the motor processing and testing in a professional manner, and within the 30-month schedule limitation. For these reasons, support facilities such as machine and instrument shops, controlled storage area, tool rooms, offices and locker rooms are included in the test zone. The minimal instrumentation capability available at the end of the 260-SL program, or the Task I phase, must be considerably upgraded to permit rapid changeover from one test facility to another, a more automated and fail-safe operation and to take advantage of the state-of-the-art in data acquisition and control systems.

2. Ground Rules and Assumptions

a. Maximum practical use of common STE between the three major test facilities would be planned to reduce the quantity of new items needed.

b. Maximum use of automated or computerized checkout, count-down and safeguard control systems is required.

c. A 100-channel analog-to-digitial convertor and recording system with printout capability would be required.

d. All cabling to the test sites would be protected in above-ground conduit or cable-trays. Camera TV cables on the pad adjacent to the motor would be below grade and terminate in weather-proof receptacles at each designated camera station.

e. Schedule limitations dictate the necessity of a second CCT facility.

III.F. Static Testing (cont)

f. Data acquisition requirements are the same as defined for the Task I study.

g. Use of surplus or borrowed equipment from the Sacramento facility will be planned whenever availability can be projected.

3. Facility Requirements and Design Criteria

a. CCT No. 1 and No. 2 (New)

(1) General

No changes are required in the existing facility (CCT No. 1) with the exception of the number of data channels and instrumentation equipment available at the terminal room (discussed below). The new CCT would have the same capability and utility features of the present facility, but would be of a smaller size to handle the particular 260-FL motor under consideration in this study.

(2) Instrumentation and Control Channel Requirements

Type	Number
Strain gage type channels	60
Linear motion or potentiometric	20 flexseal 36 LITVC
Thermocouple	20 constant 30 samples
Control channels	30
High frequency	14

III.F. Static Testing (cont)

Type	Number
Voltage, current, event, etc.	36
Motion picture	9
Television	4
Weather motion	4 (CCT No. 1 only)
Voice (interphone)	3

b. Nozzle/TVC Assembly and Checkout Building

(1) General

This facility must contain sufficient area, vertical clearance, and hoist capacity to lift and position two nozzle assemblies (less aft exit-cone) on assembly and checkout fixtures. One bay should be suitably revetted to permit high pressure proof testing of the flexseal. An enclosed control room with automated TVC functional checkout equipment should be planned. An area for hydraulic power supply unit operation, maintenance and storage would be needed as well for repair and checkout of TVC system hydraulic components. A small shop for storage and checkout of system electronics is also desirable. A revetted pad would be placed outside and adjacent to this building for liquid injectant tankage and controls should this method of TVC be selected. All areas where electronic systems are to be located must have full air-conditioning and humidity control. Ideally, the entire building should be so equipped.

III.F. Static Testing (cont)

(2) Instrumentation and Equipment Requirements

Type	Number
Strain gage channels	12
Linear motion	8 flexseal 28 LITVC
Control channels	4
Voltage, current, event	12
Cameras - movie	2
Television	2
Voice (interphone)	2
Optical Alignment System	1 set
Leak Test (He) System	1
TVC Checkout and Control Unit	1

c. Instrumentation Center and Control Room

(1) General

In addition to housing all of the required instrumentation and control systems, this facility must include space for visitors' viewing of the test and a small engineering office. The enlarged test crew size and increased equipment requirements by themselves dictate the need for extensive modifications to the existing instrumentation center or possibly even a new building. Complete air-conditioning and humidity control is required.

III.F. Static Testing (cont)

(2) Instrumentation and Equipment Requirements

(a) Recorders

(1) Oscillographs (6)

(2) Analog-to-digital converter and recorder (100 ch)

(3) Direct writing (strip charts) (2)

(4) Magnetic tape (FM) (1)

(5) Elapsed time counter (2)

(6) Ballistic integrator (2 ch.)

(b) Signal conditioning

(c) Range and calibration

(d) Time base generator

(e) TV receivers (4)

(f) TV recorder and switching unit

(g) Firing control console

(h) All systems control and status indication

(i) Igniter control and release units (2 if aft-end igniter is used)

(j) TVC control console and servoamplifier system (4 ch.)

(k) Patching unit

(l) Intercom

(m) Camera control

(n) Weather monitors

III.F. Static Testing (cont)

d. Instrument Shop

A new facility to house instrumentation support services is required. The capability to perform maintenance and limited calibration on electronic components is a requisite of a time-limited test program. The building should include office space for at least two people, a small dark room for camera and oscillograph loading, an oscillograph developing unit, a film and record storage area and a moderately equipped shop. This building should be located fairly close to the control room.

e. Machine Shop and Inert Storage Building

This new building should provide facilities for control room controlled item storage, bulk storage area and a small machine shop. Location of this building should be such that it is convenient to the activities being conducted at the CCT and control room area.

f. Area Office and Personnel Building

A new facility, centrally located within the test area, is needed to accommodate a variety of functions associated with a large scale test operation. Space should be provided for the following:

(1) Offices for six engineering and supervisory personnel

(2) Desk space for an additional six people

(3) An area receptionist and paging service

(4) Lockers, washroom and lavatory facilities for 50 to 60 employees

(5) A canteen-type lunchroom with tables and benches

III.F. Static Testing (cont)

This building should be of concrete block type construction and fully air-conditioned.

g. Instrumentation Transfer Room

A building adequately protected from the thermal, acoustic and dynamic environment of a 260-FL motor firing is required to house the terminations of control room-to-CCT area cabling, the test site selection (or patching) equipment, charge amplifiers and other miscellaenous electrical and instrumentation equipment. The existing terminal room at CCT No. 1 would still be used but only for termination of motor instrumentation cabling, power relays and X power supplies. A similarly equipped terminal room would be required adjacent to CCT No. 2.

h. GSE Pads

A concrete pad with at least three sides protected from the thermal and overpressure effects of a minor motor malfunction, such as a nozzle or exit cone failure, should be incorporated at each CCT to permit installation of the major GSE items associated with a test firing or hydrostatic proof test. Equipment which would be positioned at this site during a test would include the following:

(1) Hydraulic power supply unit

(2) CO_2 quench system receiver

(3) A 4000 gal (15 m^3) fluid storage tank (for hydrotest and/or water quench system)

(4) Hydrotest pumps, valves, miscellaneous components

(5) LITVC injectant tank and controls

III.F. Static Testing (cont)

Adjacent to these pads would be installed the 650-cu-ft (19.5 m^3) high pressure GN_2 storage vessels (if LITVC is selected) or a smaller unit for general service if a flexseal nozzle is used.

A below-grade trench or conduit carrying all piping to the motor would terminate in this enclosure. Water, lighting, and 110, 220, 440vac, 200 amp, electrical service would be required at the pad. In addition, cabling for remote control of the various equipment and monitoring instrumentation would be needed.

4. Special Test Equipment Requirements

Whenever possible, STE will be designed to be used at both test facilities, and will only be duplicated where a backup capability is required or movement is not practical. Specific items which will be transferred between facilities as needed are:

a. Igniter handling, support, retention and release (if applicable) tooling

b. Posttest quench equipment (less piping)

c. Anti-flight system

d. LITVC (if applivable) tankage, valving, pressure regulation system and terminal supply lines

e. Leak test closures

f. Helium leak detection equipment

g. Hydrotest adapters, high volume fill and drain pump, piping, mix tank, relief valves, etc.

h. Upper side force measurement assemblies and side-force calibration equipment

III.F. Static Testing (cont)

i. Camera enclosures and mounting assemblies

j. Hydraulic power supply units

The items listed below will be semi-permanently installed at each CCT facility and no effort made to shift them from one to the other as test or motor processing operations are transferred.

a. Thrust adapter base ring assembly

b. All thrust take-out equipment at forward head and lower side force assemblies

c. High pressure GN_2 supply tanks

d. Below-grade plumbing from GSE pad to motor

5. Description of New or Modified Test Facilities

a. Cast/Cure/Test Facility

The new CCT was described in Section III.E. In relation to this facility's function in the testing of 260-FL motors, there will be no significant differences from the capabilities or equipment used on the existing CCT. The shorter depth of the new caisson negates the need for the circular thrust adapter (spacer) which must be used in CCT No. 1. There will be a small instrumentation terminal room adjacent to the caisson for installation of cable termination panels and shock-mounted relay boxes. Permanently installed instrumentation and control cables will run from this room to the new instrumentation transfer room located between the two CCT facilities. Cables will be installed below grade to each camera or TV position in the immediate vicinity of the CCT.

III.F. Static Testing (cont)

b. Instrumentation Center and Control Room

The fact that the present instrumentation center at DCP (Bldg. 21511) would not be satisfactory for a test program of any consequence was established early in the Phase I study. The only decision to be made was whether it would be more practical to modify or add on to the existing building or to build a completely new facility.

Two important factors pointed conclusively to the approach selected, that of enlarging the present facility. First, was the cost involved. Duplicating the available 1000 sq ft (93 m^2) of equipment room, lavatory and instrumentation space would cost approximately $80,000. Secondly, Bldg. 21511 is ideally located to take advantage of existing roads, power lines, and utilities while still being operationally convenient to the CCT area.

A control room layout was designed which could accommodate the instrumentation and control systems. Significantly, all of the proposed equipment and work area very readily could be adapted to a relatively straightforward 575 sq ft (53 m^2) enlargement of the present building. The proposed control room layout is shown in Figure 12. A visitor viewing area and engineering office also are incorporated in this plan.

The addition to Bldg. 21511 would be of reinforced concrete construction and would be revetted with earth and rock on the east side and overhead. The existing heating and air-conditioning system would be supplemented to handle the larger building. The equipment room presently has much unused floor space which could be converted to additional offices or work space if needed.

c. Test Support Complex

Immediately to the south and east of the instrumentation center will be located a complex of three buildings (see area map, Figure 13)

III.F. Static Firing (cont)

housing various support functions. These are basically buildings which, while desirable, could not be justified for the previous programs because of their limited scope. The size of the work force assigned to this area for the Phase A motor processing and test program, and the complexity of the entire operation requires the availability of these facilities and the services they provide. The three new buildings are described below:

(1) Instrument Shop

This building would be readily accessible to the instrumentation center and would contain about 800 sq ft (74 m^2). All storage, maintenance, repair and calibration of instrumentation components would be accomplished here. In addition, there would be a small dark room for film and oscillograph loading and for developing of oscillograph records. The other functional areas provided are shown in the floor plan (Figure 14). This building would be of block construction and would be fully air-conditioned with humidity control. It would be equipped with the usual shop equipment such as oscilloscope, volt meters, signal generator, test bench and working standards.

(2) Area Office and Personnel Center

A 1200 sq ft (112 m^2) building is proposed to provide space for personnel requirements such as locker room, lavatories, a canteen-type lunchroom and offices for engineering and supervising staff. The location of this building makes it accessible to those assigned to the CCT area to the east and the adjacent support facilities. This building would also be of block-type construction and fully air-conditioned. The proposed floor plan is shown in Figure 15.

III.F. Static Firing (cont)

(3) Utility Services Building

This facility will house a small machine shop, tool crib, a controlled-access stores area, and a larger in-process storage area. The machine shop would have a minimal equipment inventory, including a drill-press, grinders, cut-off saw, welding unit, small lathe and layout table. There would be no overhead crane in this building but a ramp and large access door to the storage area is provided (Figure 16).

d. Nozzle/TVC Assembly and Checkout Building

This building will serve several important functions associated with the pre-test nozzle and TVC subsystem. These include:

(1) Proof, leak and functional testing of the flexseal (if assembled at DCP).

(2) Nozzle and TVC subsystem build-up, leak testing, inspection and instrumentation.

(3) Installation of TVC components on the nozzle assembly.

(4) Alignment, null-positioning, and functional verification of TVC system (movable nozzle).

(5) Assembly, leak testing, flow calibration and functional testing (LITVC).

(6) Post-test disassembly, inspection, refurbishment and/or disposition of components.

III.F. Static Firing (cont)

(7) Hydraulic GSE maintenance and storage.

(8) TVC hydraulic and electronic component checkout and storage.

A 35 x 45 ft (11 x 14 m) building (Figure 17) with two high bays serviced by a 20 ton (18,000 Kg) rated capacity overhead hoist is proposed. The east bay, where all high pressure testing would be conducted, is enclosed by reinforced concrete walls for maximum protection from any part failure. Blast-proof viewing windows would be provided between the control room and the bays. Control and monitoring equipment for a programed checkout of TVC systems is installed in the control room, although simulated duty-cycle and all system response functions may be controlled remotely from and recorded in the main instrumentation center, as would be the case on a static firing.

All high pressure lines (hydraulic and injectant) would be brought into the test bays in below floor-level trenches, with safety covers. A revetted pad would be provided on the south side of the building should LITVC be employed.

The building is located approximately 900 ft (270 m) west of CCT No. 1 on the south side of the existing roadway. A rock and earth barricade on the east side of the building will provide structural protection should a motor malfunction occur during a static firing. The building is not designed for occupancy during a firing.

e. Instrumentation Transfer Room

This facility functions primarily as the switching center for all instrumentation and control cabling running from the control room to the 3 test sites (CCT 1 and 2 and Nozzle/TVC building).

III.F. Static Firing (cont)

In addition to the site-selecting or switching equipment, the more vulnerable electronic components, such as charge amplifiers and voltage reference units would be installed at this site. Reinforced concrete construction above grade, is proposed, with equipment for maintaining an acceptable temperature and humidity condition installed.

f. Ground Support Equipment Enclosure

A 14 x 28 ft (4.3 x 8.6 m) concrete pad, with 8 ft (2.4 m) high concrete walls on three sides is planned at each CCT. This facility will provide a protected location for the temporary installation of the main GSE items being used during a static test or hydrostatic test. All necessary electrical power, water service and control monitoring cabling would be provided at the pad. A below-grade covered trench for installation of piping is included. Each GSE pad will have a removable hinged roof for weather protection and for easy placement of equipment in the enclosure by the stiff-leg derrick.

6. <u>Description of Special Test Equipment (STE)</u>

As there will be at least a 2.5 month period between static test firings, the stated objective of transferring STE between test sites, when needed for a particular test, will be met to a large degree. In some cases however, it becomes technically or operationally impractical to remove portions of the set-up after each test, particularly those items which may stay in place during motor processing and would involve considerable effort to achieve the desired alignment or positioning each time the installation is made. In the discussion which follows, the STE requirements are divided into two major groupings; those items which must be procured for use at the new CCT and those which are to be used at both facilities and are assumed available from the Task I program.

III.F. Static Firing (cont)

a. New STE Requirements

(1) Base Support Ring

The new CCT facility is designed for one particular 260-FL motor and will therefore be some 33 ft (10.1 in.) shorter than the existing facility. For this reason, no thrust adapter (spacer) will be required. However, in order to provide a level platform for mounting of the load cells and hydraulic jacks, a base ring assembly will be needed. This ring will also distribute the nearly 11 million lb (54,000,000N) of combined motor weight and thrust to the caisson floor and raise the load cell assemblies above the probable water-line which would be expected should the sump pumps fail during post-test water deluge or a heavy rainstorm. The top face of the ring would be machined to close tolerances and the assembly would be leveled and aligned with the caisson centerline during initial installation. It would not be disturbed while any motors remained to be processed or tested.

(2) Thrust Take-Out System

The basic motor support and thrust take-out system, described in the Task I final report and located at the forward section of the motor would be duplicated, with minor exceptions, at the new CCT. This equipment consists of the following:

(a) Three 5 million lbf (22,000,000N) rated capacity load cells with mounting pedestals.

(b) Three 1.5 million lbf (6,700,000N) rated capacity hydraulic jacks; the present system has 1.2 million lbf (5,400,000N) rated capacity units.

III.F. Static Firing (cont)

(c) Three laminated rubber/steel isolation pads (for lateral freedom at each load cell).

(d) A thrust collector/motor support ring identical to the existing T-430007-101 assembly.

(e) A side-force reaction and measuring system at the south and east station of the thrust ring. Each assembly consists of two 150K (670,000N) rated capacity universal flexures, a 100K (445,000N) rated capacity load cell and a stabilizer rod, with associated mounting plates.

After the initial installation and alignment of the entire forward portion of the thrust take-out system, only periodic verification of alignment would be needed, as the set-up would never be disturbed, assuming normal motor operation. The feasibility of transferring the three large load cells between facilities was studied and rejected. Using the criteria that one spare load cell must be purchased as a back-up under this plan ($16,000) and determining that the labor costs associated with 14 removal and reinstallation operations of the three cells would be about $28,000, it became obvious that an economic stand-off and a definite technical advantage existed with the selection of two complete sets of axial load cell assemblies. This plan also provides spare load cells (3) to be used in any emergency.

The upper horizontal stabilizer and side-force measurement assemblies will be used at both facilities. These are relatively easy to remove and install and must be disassembled whenever a motor is moved anyway. Spare universal flexures, load cells and stabilizer assemblies would be purchased to permit testing to continue on-schedule should any component failure occur.

III.F. Static Firing (cont)

(3) Hydraulic Power-Supply Unit

A second hydraulic GPU would be necessary to support the double CCT operation. The system proposed and discussed in the Task I study would be stationed at the nozzle/TVC assembly and checkout building and a new unit purchased and used at CCT Nos. 1 and 2 as needed. A more sophisticated and versatile power supply is recommended for this phase, one utilizing components below their rated capacity and readily adaptable to higher flow or pressure outputs. A variable volume pump unit, rated at 70 gpm (1900 cm^3/s) at 300 psi (2070N/cm^2) with standard accumulators, filters and remote control and monitoring features has been selected and a firm price quote obtained.

(4) GN_2 Storage Vessel

A substantial volume of high pressure GN_2 will be needed if a LITVC system is selected for the 260-FL motor. There are presently surplus 650 cu ft (18.4 m^3) tanks at the Sacramento facility which should be available. The tanks are rated for 3000 psi (2070N/cm^2) service. For the relatively small cost involved for shipment and installation, it is desirable to have one such vessel installed to serve each CCT facility, rather than attempt to service both with a single installation, and have high-pressure lines running up to 1000 ft (305 m) in length with accompanying high pressure drops. The tanks would be installed on saddles adjacent to each GSE pad, approximately 200 feet (61 m) from each CCT.

(5) Fluid Storage Tank

A 4000 gal (15.1 m^3) storage vessel is required for use during the hydrostatic test and for the post-test water deluge system. The

III.F. Static Firing (cont)

chemical additives used during the proof test would be mixed in this tank and metered into the 260-FL chamber during the fill operation. The vessel would be constructed so as to be readily transportable between the two CCTs for installation on the GSE pad. If the Task I 260-FL case is available when this program is initiated, the entire hydrostatic test procedure could be revised and would become a more efficient operation. The surplus case would be installed approximately halfway between the CCT facilities and used as a common storage, mixing, and dispensing vessel. The required hydrotest fluid, with additives premixed, could be available before the fill operation is to start and would expedite this procedure. After each proof test, the surplus case would be refilled from the 260-FL chamber, simplifying the fluid disposal operation and allowing reuse of the inhibited water. Otherwise, the excess would be disposed of in the manner utilized on the 260-SL-3 proof test, dumping at sea.

The cost of the proposed 4000 gal (15.1 m^3) tank was estimated on the basis of a mild steel spherical vessel having provisions for the necessary plumbing connections.

(6) Hydrotest Fill/Drain Pump

A 500 gpm (13,500 cm^3s) rated capacity pump will be used for the transfer of water into and out of the 260-FL chambers being proof-tested. Cost to lease such a pump, as was done at the 260-SL-3 hydrostatic proof test, for the 24-months it would be needed is excessive when compared with the acquisition cost. The amount listed in the cost summary for this item also includes the required piping, valves, controls and palletized installation which will enable rapid hook-up to the storage tank or motor chamber.

III.F. Static Firing (cont)

(7) Chamber Coolant System

Past 260-SL testing has demonstrated the need for a simple water deluge system which can apply large quantities of water to the motor outside surfaces in the event of premature insulation exposure or a primary quench system failure. A simple toroidal pipe assembly suspended beneath the aft handling ring and incorporating many discharge holes is proposed. The water released from this pipe, upon actuation of a remotely controlled valve, would flow down the case sidewall. Additional nozzles would be directed to each head of the case.

(8) Igniter Sled Assembly

If aft-end ignition is selected for the 260-FL motors, a holding/flyaway fixture for each test will be required. This assembly will be of a similar design as the ones used on the three 260-SL motors tested to date, and the unit cost will be comparable. Each unit is non-reusable because of impact damage and the total cost for eight units is fairly significant.

b. STE Available from Task I

The following items of test equipment will be moved as necessary between the two CCT facilities for use during firing or hydrotest operations.

(1) Flight retention assembly

(2) Aft end igniter support system and track assembly

(3) Post-test motor quench system

(4) Upper side force measurement system

(5) LITVC injectant tank, control valves and supply lines

III.F. Static Firing (cont)

A description of these items and the acquisition cost were provided in the Task I Final Report. It is assumed that this equipment would be available for the Task II test program.

7. Instrumentation and Control Systems Description

The general approach used in the selection of the instrumentation system was to provide workable, reliable equipment which represents the latest in the state-of-the-art where necessary, and to make use of existing equipment where possible.

The block diagrams developed in this study (Figure 18) are all workable systems, but do not represent a final design. A significant amount of study has gone into the type of equipment which would be most suitable for the specific applications, especially the long input lines and the need for selection of three test bays. The equipment costs resulting from this study, and quoted elsewhere, are current and should be quite accurate. The installation costs were estimated on the basis of a similar job in test Zone J at the Sacramento facility.

a. Data Acquisition

The data acquisition systems are relatively straightforward. A six-wire strain gage system is used: transducers will be standardized. The thermocouple system employs a "hot" reference junction at each test stand resulting in improved performance and low cable costs.

The signal conditioning units are off-the-shelf, self-contained power and calibration units. Typical manufacturers are B and F Industries and Astro Data. The test stand selector units are hermetically sealed gold plated "Ledex" switches, used successfully at Sacramento.

III.F. Static Firing (cont)

The dc amplifiers are floating differential input isolated units. In each system, the input ground is at the test stand. The output ground is in the control room.

A high level patch system is included for recorder selection.

All channels will be electrically calibrated simultaneously from a master control panel. The strain gage system will use shunts and the position and thermocouple systems will use voltage substitutions. The high frequency system will use a 1 KHz 1 volt signal.

The prime data recording will be in digital form on magnetic tape. The system planned will have sufficient computer capability that data in engineering units can be printed on the teletype printer, whether it be a pre-calibration or actual test data. The system will employ stored memory, simplifying the operation, but will also have a paper tape entry for re-programing or for diagnostics. A visual display of any channel will be available.

The digital recorder will have sufficient inputs to handle all channels. The thermocouples will be recorded via the low level inputs.

Alternate recording will be available on five oscillographs if desired. In addition, an FM magnetic tape and five 10-in. strip charts are included. A direct-write graph will be available for high frequency playback, as well as for valve functional checkouts and other pretest operations. The FM tape will include a complete playback capability.

III.F. Static Firing (cont)

Any facility type function, such as hydraulic pressures, will come straight into the control room and be displayed without going through the test stand select system.

The total facility instrumentation capability, as determined necessary for the eight motor test program, is summarized in Figure 19.

b. Auxiliary Systems

The motion picture system may be turned on either manually or via the countdown programer. Each stand will have its own pulse generators for timing excited by the master time-system. It will be necessary to purchase five new cameras, all of which will have the capability to include binary coded decimal time in each frame.

The closed circuit television system will include four monitors, four control systems, and a magnetic video recorder, selectable to any one of the monitors. There will be a select system in the transfer room to allow choice of any combination of camera outlets from the three stands into the four systems. Pan, tilt and zoom capabilities are included.

c. Controls

In addition to routine on-off control systems, it is necessary to add the TVC programer and drivers. The programer will be a magnetic tape system, interfacing through buffer amplifiers and valve drivers. Excitation for LVDT units, as well as position feedback provisons are included. The tapes will be generated at Sacramento or some other facility.

A countdown sequencer with appropriate system interlocks will be provided, as well as a system status panel for use of the test conductor. Igniter motor ignition and retraction controls are included.

III.F. Static Firing (cont)

The intra-facility distances involved require the use of power relays. These must be located in the terminal room adjacent to each CCT, and will be high-g type units, with shock and vibration isolation.

d. Support Equipment

The test rate will require maintenance of the data acquisition and controls equipment on the site. Shop equipment such as an oscilloscope, voltmeters, signal generators, test benches, and working standards are required and are included in the cost summary.

Contract maintenance was not explored as part of the study, but should be in the future. It is clear, however, that such skills must be available on the site.

e. Transducers

It is recommended that a minimum calibration capability be available on site. Again, this service may be contracted. However, costs for a pressure bench, readout equipment, and a thermocouple calibration setup have been included, as no contacts were made relative to obtaining contract services.

f. Cable Length Analysis

Addition of a second test facility and the TVC Checkout Building added to the complexity of selectors, the location of a selector "transfer" room, and the total length of input cables as system performance may be affected.

III.F. Static Firing (cont)

Control systems requiring solenoid valve operation will require dc power supplies in terminal rooms adjacent to each test bay, this being independent of where the new CCT is located. The power relays must be mounted in shock resistant enclosures.

Careful consideration had to be given to the data acquisition systems relative to frequency response, calibration errors, power losses, noise, and phase shift on amplifier inputs as well as outputs.

Each of the major acquisition systems was analyzed relative to cost and performance trade-offs, and are summarized below.

(1) Strain Gage System

Generally, a frequency response to 300 Hz is adequate for these data. The system chosen should result in data flat to 500 Hz and perhaps 10% (1db) down at 1 KHz, all relative to the dc response. The analysis is based on data from Reference (b) p. 81.

The use of 20 gage versus 16 gage cable was studied relative to calibration errors and excitation versus costs. The line resistance due to the use of 16 ga cable introduces a 0.035% error in shunt calibration, assuming standard Aerojet resistors, and a voltage drop of 1 volts. The corresponding values for 20 gage are 0.08% and 2.7 volts. The cost differential is $23,500, in favor of using 20 gage. It is concluded that 20 gage cable should be used with shunt resistors of non-standard sizes (by the amount of the line resistance) and the power supply should be set at about 12.7 volts to achieve 10 volts across the bridge. The amplifier gain could also be set higher to accommodate the loss.

Reference (b) "Data Transmission and Handling Study" October 1962, for MSFC, Mississippi Test Facility, AETRON. NAS8-3444-A20-102.

III.F. Static Firing (cont)

(2) Thermocouple, Linear Motion, Events

These systems are essentially low frequency and acquiring response flat to 500 Hz should present no problem. Line resistance errors in the thermocouple systems can be accommodated with compensation resistors. If event timing to better than 1 millisecond is required, line loading can be used.

(3) High Frequency

Use of charge amplifiers for the piezoelectric system places certain demands on the cable plant. The amplifier chosen has an input capacity limitation of 30,000 pf and 1 microfarad output limitation. Using low-capacity RG-62/U coaxial input cable, and locating the charge amplifiers in the transfer room, the input capacity is 27,000 pg, and the output is approximately 0.1 microfarad. There is adequate margin on both input and output.

The charge amplifiers would not function properly if placed in the control room, and if placed near each test stand one doubles the investment. Further, the vibration environment at the test stands is undesirable.

III.F. Static Firing (cont)

8. Facilities and STE Cost Summary

FACILITIES		
Instrument Shop		$ 29,300
Nozzle Assy and Checkout Bldg.		198,400
Utility Services Bldg.		64,700
Personnel Center		41,800
Instrumentation and Control Center		27,900
Instrumentation Transfer Room		16,000
GSE Pad (2 each)		21,500
Instrumentation Facilities		820,000
	Subtotal	$1,219,600
EQUIPMENT		
Mechanical Systems		$ 391,300/589,300*
Instrumentation and Controls		175,000/180,000*
	Subtotal	$ 566,300/769,300*
	Grand total	$1,785,900/1,988,900*

*Applies when using aft-end ignition

III. Phase A - 8 Motor Program (cont)

G. MOTOR SUBSYSTEMS

1. Ignition System

Consideration was given to the possibility of processing igniters at the Dade County Plant. This option would have the advantage of utilizing labor available during slack periods in motor processing. The cost trade for the 30-motor program is discussed in detail later in Phase B. A similar trade was examined for the 8-motor program and, although not presented in detail here, showed that ten igniters could be processed at the Aerojet Solid Propulsion Company at Sacramento for considerably less cost than would be required for a new igniter processing facility at the Dade County Plant.

However, from the standpoint of operational convenience and safety, it is apparent that a storage facility will be necessary for any on-plant ignition systems or pyrotechnic components needed for batch test motors. There is at present no facility meeting the storage criteria. Therefore, a small igniter magazine, approximately 20 by 25 ft (6.1 by 7.6 m), would be provided at the location shown in Figure 22. The estimated cost of this environmentally-controlled, barricated structure is $48,600.

IV. PHASE B - 30 MOTOR PROGRAM

A. STUDY CRITERIA AND GROUND RULES

The objective of this phase is to define the optimum facilities required to cast, cure, but not static test fire 30 full-length 260-in.(6.6m)-dia solid rocket motors in a period of five years. The criteria for facility acceptability in their adequacy for producing high-quality large motors at minimum cost. Optimization is on the basis of minimum overall cost per motor for this phase only.

IV.A. Study Criteria and Ground Rules (cont)

To implement the objectives of Phase B, ground rules were established for developing the process plan and defining the scope of facilities requirements.

1. It is presumed that the facilities defined for Phase A would be existent and would have been demonstrated to be adequate for that program.

2. Motor hardware components would be available at two-month intervals, as needed. That is, availability is not a constraint on processing operations, but no provision is allowed for storage of major components, other than those being processed.

3. All processing and testing operations would be performed nominally with three work shifts on a five-day week. Operations which are necessarily continuous in nature, such as casting, curing, and temperature conditioning, would be performed on a seven-day week at the appropriate work level.

4. While consideration of the movement of loaded motors was excluded from this effort, an interface with that operation was established because of the major influence expected from operational and facilities requirements. Basically, it was assumed that such facilities would exist and would be available for on-plant motor case transportation and handling. Also, the location of certain new facilities would be influenced by the loaded motor facilities concept and related cost factors.

5. As an extension of the interface interpretation, motor processing operations were defined to include all assembly operations through stage assembly, using the configuration shown in Figure 20 as the baseline, as derived from the first stage of the 260-SIVB vehicle, Reference (a). However, all ordnance components would be excluded and shipped separately for assembly on the launch pad.

IV. Phase B - 30 Motor Program (cont)

B. OVERALL PLAN

1. Approach

The approach to planning the facilities for Phase B is similar to that established in Phase A. The significant differences involve schedule, the elimination of static testing, and the interface with loaded motor handling facilities.

The effect of schedule is extremely important in the consideration of cast-cure-test facilities. A careful analysis of the process steps in the caisson showed that the two CCT facilities provided in Phase A would be adequate, but with little margin. A facility process schedule was developed, as shown in Figure 21, to describe the major operations on a continuous cycle basis. The span times making up the 114 day in-caisson processing cycle are realistic and do not depend upon maximum rated capacity. For example, the propellant casting time of 17.3 days does not depend upon the reserve capacity provided by the additional propellant mix station selected for this phase. On the other hand, possible additional operations such as complete nondestructive testing of the cured propellant grain or periodic static testing, which have not been specified, would have a significant effect on the minimum possible processing cycle, and would require either a stretched-out schedule or an additional cast-cure-test facility.

The elimination of static testing as a requirement means that adjacent facilities do not have to be exposed to that severe environment on a periodic basis. Also the caisson does not have to be converted for different functions as each motor is processed. For example, the environmental shroud can remain in place.

IV.B. Overall Plan (cont)

Establishment of an interface with loaded motor handling facilities was necessary, as mentioned in the previous section, even though the operations are not a part of this study, because the facilities can be used in common with empty case handling.

2. Facilities Layout

The principal facilities added for Phase B were an additional propellant mix station, an insulation facility, and an igniter processing facility. The relative locations of each are shown in Figure 22. The canal extension and the 2000-ton (1,800,000 kg) derricks are presumed to be needed for loaded motor handling and are not part of the facilities included in this study, except to the degree previously stated. The separation of facilities for explosive hazard protection was discussed in Phase A. The placement of the facilities for Phase B is within those criteria.

C. CASE HANDLING

1. Existing Facilities

a. Previous Experience

The short-length motor cases were delivered dockside by barge and transported overland on a strongback transporter using tandem bars to connect eight eight-wheel pneumatic tire dollies. The transporter planned for the Task I and Phase A programs was of the same concept, except that double tandems were required to connect the 128 pneumatic tires.

Lifting of the short-length motor cases at the CCT facility was accomplished with a stiff-leg derrick and two portable cranes. The

IV.C. Case Handling (cont)

full-length cases for Task I and Phase A were to be lifted in the same manner, except that the stiff-leg derrick boom was extend to gain the required height.

b. Facilities for Loaded Motors

It is expected that the loaded motors would be placed on a special transporter as close as is practical to the CCT caisson. The motors would be lifted with a 2000-ton (1,800,000 Kg) rated capacity double-boom derrick. The transporter would be moved on rails onto a special barge in a graving dock constructed on the site. The existing C-111 canal would be extended westward along the planned case delivery route for Phase A to provide water transportation for motor delivery. Thus, at each CCT there would be an "existing" 300-ton (270,000 Kg) rated capacity stiff-leg derrick, a 2000-ton (1,800,000 Kg) rated capacity double boom derrick, a set of rails, and a canal to consider for case handling.

2. Special Requirements

a. Load Definition

The motor cases for Phase B, as received from the case fabricator, would be equipped with handling rings adequate for lifting the loaded motor. The rings would be heavier and larger in diameter. It is estimated that the case with handling rings would weigh approximately 300 tons (270,000 Kg) and the total barge load, including case, transporter, handling rings, and turning rolls would weigh approximately 400 tons (360,000 Kg), or roughly 50% more than estimated for the Phase A loads. The "existing" stiff-leg derricks at the CCT caissons would be inadequate for this task.

IV.C. Case Handling (cont)

b. Location of Insulation Facility

The location of the new insulation facility is directly related to case movement requirements. Modification of the G. P. Building complex for insulation of the Phase B cases places a much greater demand on case movements requirements. Construction of new insulation facility at the case receiving area is a more expensive option for that operation.

3. Selection of Facilities

a. Case Transporter

The continued use of the pneumatic-tire truck transporter concept is no longer feasible for the Phase B loads. The possibility of distributing the load over approximately 180 to 200 wheels appears to be both remote and expensive. Maneuvering of a transporter of this magnitude would be extremely difficult. Therefore, the concept of steel wheels on rails was selected. Rails would already be installed at the CCT facilities for the loaded motor transporter. A transporter concept was prepared, as shown in Figure 23, to use two of the four rails at the CCT. A two-rail system would also be installed at the insulation facility, which will require a barge slip off the canal extension, as shown in Figure 22. The transporter consists of two independent four-wheel trucks, which support the case at the trunnions. The case turning rolls would be built into the trucks and would be raised for trunnion removal and case revolving. A single pair of transporter trucks would be adequate to meet program schedule requirements. The cost of the transporter is estimated to be $170,000.

b. Case Lifting at CCT

The insulated cases would be lifted using the 2000 ton (1,800,000 Kg) rated capacity double-boom derrick. The case would be rotated

IV.C. Case Handling (cont)

on the transporter and lifted into place. No additional facilities would be required.

D. CASE INSULATION

1. Existing Facilities

The existing facilities assumed for Phase B are those which were derived for Phase A and described in Section III.D.1 of this report.

2. Special Process Requirements

There are no special process requirements for this program phase, other than to insulate thirty 260-FL motors in accordance with the process plan established for both the 1- and 8-motor programs.

3. Facility Options

Two insulation processing facility options exist:

Option 1: Use modified "existing" G. P. Building complex as defined for the 1- and 8-motor programs.

Option 2: A. Construct a new insulation facility along the canal extension.

B. Construct a new insulation facility along the canal extension which includes one 150-gal (0.73 m^3) Baker-Perkins 16 PVM vertical batch mixer.

IV.D. Case Insulation (cont)

Option 1 involves transporting the case from the canal unloading dock to the G. P. Building complex, then returning the chamber to the CCT after insulation operations. This option involves the cost of sixty chamber movements, plus providing a larger environmental enclosure building to accommodate the larger case handling rings.

The second option is to construct a new, self-contained insulation processing facility adjacent to the canal extension. The selected location of the new facility relative to the CCT and canal is shown in Figure 22. A sketch of the facility layout is shown in Figure 24. The chamber is moved by barge to a loading dock at the east end. The chamber and transporter are pulled from the barge into the facility.

The insulation facility is self-contained, in that all materials, equipment, and utilities are available at the building. The main building, which houses the chamber, transporter, and turning rolls, is approximately 138-ft (42 m)-long, 40-ft (12 m)-wide and 40-ft (12 m)-high. Once the chamber is moved into the building and the doors are closed, the environmental system is started. Because of its long length, the lighting/equipment truss is installed in segments. The utilities, heating ducts, and air, nitrogen, and vacuum lines are installed. Insulation processing operations are then begun. The other section of the building contains a raw material storage area, tooling storage and parking areas, a dispensing area and equipment room, and office space. For option 2B, a 150-gal (0.57 m^3) Baker-Perkins 16 PVM vertical mixer is included. The IBT batch size capacity for this mixer is 1500 lb (680 Kg).

4. Facility Option Tradeoff

The following table is an overall cost trade-off summary:

Option 1	Option 2A	Option 2B
\$617,000	\$886,000	\$1,091,000

IV.D. Case Insulation (cont)

For Option 1, the estimated cost of sixty moves is $8,000 per move, or $480,000, plus $137,000 to provide a new environmental enclosure to accommodate the larger handling rings. The cost for construction of a new facility is estimated at $886,000 including transporter rails. The estimated cost of the Baker-Perkins vertical batch mixer, including installation, for option 2B is $205,000.

The optimum facility option from a cost standpoint is continued usage of the G.P. Building complex. However, other factors must be considered such as risk, convenience, contingency, and processing optimization, and the type of transporter. First, operations required to accomplish the 3-mile (4.8 km) move from the canal unloading area to the G.P. Building complex (and return) entailed a certain degree of risk. The convenience of moving the chamber from the barge directly into the insulation processing facility reduces significantly the handling risk as opposed to that of Option 1. Convenience is found also in the fact that the proposed canal facility is completely self-contained in that tooling, equipment, and raw material storage areas and material dispensing areas are located within the facility. For option 2B, a vertical batch mixer is included. The processing and handling convenience is difficult to justify for the one or eight-motor program, but over the longer term 30-motor program, the self-contained facility may prove to be more economical. Finally, for reasons discussed in the previous section, the transporter design required for the move may not be feasible.

5. Selected Facility and Process

Option 2A, a new, self-contained insulation processing building along the canal extension, is selected as the optimum facility for processing thirty 260-FL motor chambers. The process plan and equipment will be the same as that derived for the 8-motor program (Section III.D.). The option of installing the on-site mixer would remain open.

IV. Phase B - 30 Motor Program (cont)

E. PROPELLANT PROCESSING AND CASTING

1. Raw Materials Storage and Handling

In order to maintain the motor production schedule for the Phase B program, a new lot of propellant raw materials will be required approximately every 57 days. With respect to the procurement of the oxidizer, it appears that this is not sufficient time to utilize a single set of Tote bins and still assure that the schedule will not be compromised:

	Estimated Span Time, Days
Motor Cast	17
Lot Qualification	21
Shipment (7 days each way)	14
Oxidizer Pregrind	5
	57

This leaves no time for the vendor to manufacture and cross-blend the oxidizer and load the Tote bins for return shipment. Two sets of Tote bins are required to insure adequate turnaround time. Since it will not be necessary to duplicate the bins required for in-process storage of preground oxidizer, the total number of additional Tote bins needed is 431, at an estimated cost of $258,600. No other new facilities are considered necessary for the storage and handling of propellant raw materials.

2. Mixing

One of the considerations presented in the Phase A propellant mixing discussion was the possibility of the loss of the use of a mix station.

IV.E. Propellant Processing and Casting (cont)

The adequacy of casting a motor at the rate available from only two mix stations was stated in the process guidelines of the final report for Contract NAS3-12002. However, the schedule penalty is significant for Phase B, which is planned on a 3-shift, 5-day week. The repair and reconstruction of a mix station during the production effort could require up to 10 months. In the discussion of propellant mixing rates for Phase A, the loss of the continuous mixer was estimated to extend the casting period by 10 days. In the four month processing cycle for each motor, there are 12 to 14 weekend days available for accelerating other processing operations at each caisson to compensate for the longer cast period. If the insulation facility does not have completely independent mixing facilities, those operations must be deferred until completion of the longer casting period. The result is that for the 10-month down-time of the mix-station, all pacing operations, including insulation, must be conducted on a seven-day three-shift basis for approximately 13 months. The risk associated with the casting of five motors with the bare minimum in mixing facilities is considered to offset the estimated $1,569,000 cost of an additional vertical batch mixer.

3. Propellant Production

As discussed above, a third vertical batch mix station will be required in order to provide back-up for loss of a mix station. With this facility available, there is a cost advantage in operating it for motor casting. In addition, as shown under Contract NAS3-12002, short motor cast times are desirable from a grain quality standpoint. A study was therefore conducted to determine the compatibility of the oxidizer and fuel preparation production capabilities with the propellant production rates. As described below, by pregrinding oxidizer and by making several relatively simple modifications to the fuel preparation facility, the production of three vertical mixers and the continuous mixer can be supported. The production of SSMP oxidizer is the limiting factor.

IV.E. Propellant Processing and Casting (cont)

a. Propellant Production Capability

Based on previous analyses a production rate of 2730 lb/hr (1,240 Kg/hr) can be expected from each vertical mixer and 3,320 lb/hr (1,500 Kg/hr) from the continuous mixer. For three vertical mixers and the continuous mixer in operation a total production rate of 11,510 lb/hr (5,220 Kg/hr) could be achieved. Assuming a 7% propellant loss (samples, scrappage and loss) a total of 3.64M-lb (1,650,000 Kg) of propellant must be prepared to cast the 3.4M-lb (1,542,000 Kg) motor. At a production rate of 11,510 lb/hr (5,220 Kg/hr) the motor can be cast in 316 hr, assuming the casting process is not limiting.

b. Oxidizer Production Capability

The production capability of the oxidizer facility was calculated on the basis of the two Mikroatomizers that would be installed as planned for Task I. With two Mikroatomizers, a 2,400 lb/hr (1,090 Kg/hr) production rate for MA (50% of the rated capacity) is estimated. Based on previous experience, SSMP can be prepared at a 4000 lb/hr (1,810 Kg/hr) rate. The oxidizer blend production rate will be governed by the SSMP content in the blend. Rates for blend compositions of probable interest will be:

Blend Ratio SSMP/MA	Production Rate lb/hr	(Kg/hr)
70/30	5,714	(2,592)
65/35	6,154	(2,791)

A total of 2.547M-lb (1,155,000 Kg) of blended oxidizer is required for the motor (3.64×10^6 lb (1,651,000 Kg) propellant x 1.014 utilization factor x 0.69 oxidizer fraction). The time required for the preparation of blended oxidizer is:

IV.E. Propellant Processing and Casting (cont)

$$70/30 \text{ SSMP/HA} - \frac{2.547 \times 10^6}{\frac{5714}{\left(\frac{1,155,000}{2592}\right)}} = 446 \text{ hours}$$

$$65/35 \text{ SSMP/MA} - \frac{2.547 \times 10^6}{\frac{6154}{\left(\frac{1,155,000}{2791}\right)}} = 414 \text{ hours}$$

The production rate for the 70/30 SSMP blend would support a propellant production rate of 8,150 lb/hr (3,700 Kg/hr) while a rate of 8,800 lb/hr (3,990 Kg/hr) could be supported with a 65/35 SSMP/MA blend.

For all 260-SL motors, pregrinding of oxidizer was utilized to balance the oxidizer and propellant production rate. With five days of pregrinding, to produce 687,000 lb (312,000 Kg) of blended oxidizer, a propellant production rate of 11,150 lb/hr (5,057 Kg/hr) production rate could be supported with a 70/30 SSMP/MA. For a 65/35 SSMP/MA blend, four days of pregrinding, to produce 605,000 lb (274,000 Kg) of blended oxidizer, would support the full 11,510 lb/hr (5,220 Kg/hr) rate.

An alternative to pregrinding, blending, and dispensing of the ground and blended oxidizer into Tote bins is to pregrind and store the SSMP fraction only. Assuming that a second Mikroatomizer is installed in the grind station (in place of the existing HSMP mill), the MA production capacity is sufficient to support the projected propellant production rate from three vertical mixers and the continuous mixer. Pregrinding and storing the SSMP has the advantage of allowing only relatively freshly ground MA (less than 24 hr old) to be used in the propellant preparation which generally provides the best oxidizer powder flow properties (minimizes oxidizer addition time to the VBM and oxidizer feeder upsets in the CM). However, pregrinding and storing the SSMP oxidizer fraction also would entail certain disadvantages:

IV.E. Propellant Processing and Casting (cont)

(1) During the production run, the MA and SSMP fractions would have to be blended or else layered (unblended) in the Tote bins for a large number of batches. Use of layered grinds is totally unacceptable for the CM and undesirable for the VBM since feeding unblended MA oxidizer through the addition system is difficult.

(2) If the preground SSMP is blended with MA as the latter is produced, this operation would require additional equipment to transfer the SSMP to the blender and would interfere with the normal production of ground and blended oxidizer to the extent that the overall production rate would probably be slowed unless a second ribbon blender was installed.

Considering the above disadvantages and the fact that with a maximum of five days pregrinding of blended oxidizer the propellant production rate can be supported, it does not appear that pregrinding and storing the SSMP fraction only is an attractive alternative.

c. Premix Production Capability

The premix production rate requirements may be calculated as follows:

(% Premix in Propellant) x (Utilization Factor) x (Propellant Production Rate)

For a 11,510 lb/hr (5,220 Kg/hr) propellant production rate the premix requirements are:

$$0.30 \times 1.063 \times 11{,}510 = 3{,}670 \text{ lb/hr}$$
$$(0.30 \times 1.063 \times 5{,}220 = 1{,}660 \text{ Kg/hr})$$

To determine the capabilities of the current fuel preparation facility, processing data from the 260-SL motors was examined. The process cycle and the premix

IV.E. Propellant Processing and Casting (cont)

facility was then evaluated to determine desirable modifications. The production rate of premix is partially governed by the rate at which completed premix can be transferred from the premix metering tank. Without this limitation production is dependent on the make-up time. Process span times for the various steps in the premix preparation for 260-SL-2 are as follow

Process Step	Average Time, Minutes
Submix Preparation	72
Premix I - Preparation	46
Premix II - Preparation	162
Sample Premix to Finish	7
Finish to Complete Lab. Qual.	110
Transfer	25
	422 (7.03 hr)

Thus, if the current premix make-up cycle were limiting, the current facility and process could produce ANB-3350 premix at a rate of 3,560 lb/hr (1,610 Kg/hr)

$$\frac{12{,}500 \text{ lb/batch} \times 2 \text{ Make-Up Tanks}}{7.03 \text{ hr/batch}} = 3{,}560 \text{ lb/hr}$$

$$\left(\frac{5{,}670 \text{ Kg/batch} \times 2 \text{ Make-Up Tanks}}{7.03 \text{ hr/batch}} = 1{,}610 \text{ Kg/hr}\right)$$

For a sustained run a utilization factor of 80% would be realistic, or 0.80 x 3,560 = 2,848 lb/hr (0.80 x 1,615 - 1,292 Kg/hr).

As noted, the limiting element in the current facility and process is the premix metering or storage tank. All premix for vertical mix batches must currently be metered out of one tank and this tank must be

IV.E. Propellant Processing and Casting (cont)

emptied in order for a make-up tank to be available for a new batch. Examination of the fuel preparation facility reveals that another 1000-gal (3.78 m^3) tank is available which can be readily adapted to use as a second metering tank. This tank, the feed tank for the wiped film evaporator, is a jacketed stainless steel tank equipped with an agitator and metering pump. The modifications required to convert this unused tank into a metering tank are minor, consisting of piping and metering pump drive modifications.

A study of the process cycle data indicates that the production rate could be improved by (1) shortening the laboratory qualification time and (2) reducing the premix II preparation time.

A 40-min reduction in the average laboratory qualification time could be provided by proper lab staffing and scheduling. The premix II tests in the past were run on a low priority basis; since the premix was rarely a pacing item in propellant processing. The tests can be completed easily in less than one hour, so the 40 minute reduction is conservative.

The premix II preparation step which consists of aluminum addition and a 30-min mix period would be reduced by the change in aluminum addition method selected for Phase A. A 60-min reduction in batch cycle time can be conservatively estimated if the aluminum is discharged from bulk containers (Tote bins) through a screw-fed SWECO screen arrangement rather than drums.

A 60-min reduction in aluminum addition time and a 40-min reduction in qualification time would reduce the batch cycle time to 322 min (5.37 hr). The production rate (80% facility utilization) would then be:

$$0.80 \times \frac{12{,}500 \times 2}{5.37} = 3{,}728 \text{ lb/hr } [0.80 \times (\frac{5{,}670 \times 2}{5.37} = 1{,}688 \text{ Kg/hr})]$$

IV.E. Propellant Processing and Casting (cont)

The 3,728 lb/hr (1,688 Kg/hr) premix production rate capability at 80% utilization compares favorably with the 3,670 lb/hr (1,660 Kg/hr) rate required to support propellant production.

4. Grain Environmental Conditioning

The facilities for casting, cure and cooling of the propellant grain provided under Phase A would be entirely adequate for Phase B, with the exception that the environmental shroud would be unacceptable. Because of the desire to minimize tooling assembly operations at the CCT facility, it is particularly advantageous to have environmental shrouds that can remain in place during all phases of operation. The Phase A (or Task I) shroud would be designed to be removed for each motor and would fit over the handling rings needed for the empty motor case. Because the loaded motor handling rings, which are larger in diameter, would be in place at all times, it is necessary to provide larger diameter environmental shrouds at each CCT facility. The cost of the two shrouds is estimated to be $400,000.

The cost of the shrouds includes an allowance for inflatable baffles. These baffles are needed to maintain adequate air velocities on the motor exterior for adequate cooling rates. Since the environmental shrouds would be approximately 360 in. (9.1 m) in diameter, it is most advantageous to fill a large portion of the four ft (1.2 m) gap with a restricting device along the line of a series of baffles.

IV. Phase B - 30 Motor Program (cont)

F. SUBSYSTEM PROCESSING

1. Ignition System

a. Existing Facilities

There would be an existing igniter storage magazine at DCP. However, igniter processing facilities would exist at the Aerojet Solid Propulsion Company, Sacramento.

b. Specific Process Requirements

This task involves the processing and assembly of 33 ignition systems, either head-end or aft-end.

c. Facility and Process Options

Ignition system facility and processing options are summarized in Figure 25. The ignition system configurations are included in the Task I report.

For Option 1, the entire ignition system is processed and assembled at ASPC, Sacramento, then shipped to DCP. For Option 2, the booster is processed and assembled at ASPC, then shipped to DCP. Ignition motor processing and final ignition system assembly is completed at DCP. Ignition system processing and assembly at DCP is assumed for Option 3. The latter options included construction of a new ignition processing facility, as shown in Figure 26.

In addition to the foregoing facility options, there are two ignition motor propellant loading options available. One method is to

IV.F. Subsystem Processing (cont)

displacement-cast propellant directly into the insulated ignition motor chamber. The other method is to tray-mold casting/secondary bonding technique used for 260-SL ignition motor processing.

d. Facility and Process Option Tradeoffs

The following table was developed as an overall cost tradeoff summary:

	Option 1*	Option 2**	Option 3
Head-End			
Displace Cast			
Processing	$375,300	$ 49,500	$ 5,700
Tooling	87,600	87,600	87,600
Facilities	-	182,400	182,400
Total	$462,900	$319,500	$275,700
Tray Mold and Bond			
Processing	$289,300	$ 49,200	$ 5,400
Tooling	48,800	48,800	48,800
Facilities	-	182,400	182,400
Total	$338,100	$280,400	$236,600
Aft-End			
Displacement Cast			
Processing	$398,700	$ 56,400	$ 12,600
Tooling	86,500	86,500	86,500
Facilities	-	182,400	182,400
Total	$485,200	$325,300	$281,500
Tray Mold and Bond			
Processing	$320,300	$ 59,300	$ 15,500
Tooling	54,800	54,800	54,800
Facilities	-	182,400	182,400
Total	$375,100	$286,500	$252,700

*Option 1 processing costs include an ignition motor shipping cost of $28,300.
**Option 2 processing costs include an ignition motor booster cost of $900.

IV.F. Subsystem Processing (cont)

(1) Processing Method

As seen in the preceding table, the tray-mold and bond technique is consistently less expensive than the displacement cast, both in tooling and in direct labor charges. Each method was optimized (for the ASPC facility) on the basis of the number of propellant batches and cores, or tray molds. The igniter boosters would be processed with 9 cores and four 60-lb (27 Kg) batches. For displacement casting, the fore end igniter would be processed with three cores and 11 1,500 lb (680 Kg) batches, and the aft end igniter would be processed with three cores and 11 3,350 lb (1,520 Kg) batches. For the tray molds, the fore end igniter would require 24 50 lb (23 Kg) trays and nine 1,750 lb (790 Kg) batches, while the aft end igniter would require thirty 120 lb (54 Kg) trays, nine 4,700 lb (2,030 Kg) batches, and one 3,200 lb (1,500 Kg) batch.

(2) Type of Igniter

As is evident from the preceding table, the fore-end igniter is less expensive than the aft-end configuration. This is entirely due to the size of the igniter and is not a facility factor.

(3) Facility Options

The summary table shows Option 3 to be the least expensive thus justifying the construction of an igniter processing facility. There are two factors which are important in the evaluation of these results.

(a) DCP Labor

No direct labor charges are shown for processing at DCP (Options 2 and 3). The reasoning is that labor utilization on this

IV.F. Subsystem Processing (cont)

program would vary widely, depending on the processing operations being conducted. The peak manpower requirements occur during the casting of the 260-FL motors. It is presumed that all personnel would be permanent, to avoid training costs, thus leaving a surplus during other periods, when the igniters would be processed. Presumably the personnel would be carried on a level-of-effort basis, so that the overall labor cost would not increase because of igniter processing. The only processing charges are for propellant materials.

(b) Igniter Booster Processing

The difference between Options 2 and 3 is in the processing of the igniter booster. The reason for this difference is that the skills for processing the pyrotechnic components would not ordinarily be available at DCP, where it is assumed that no other similar programs would be in process. Thus, while Option 3 obviously is going to show a lower processing cost, there would be at least some training costs involved which are not estimated herein. The facilities for Options 2 and 3 are essentially identical, so that the choice would be a matter of personnel availability at the time the decision would be made.

e. Selection of Facilities

The only facility in question is the igniter assembly building, located near the igniter magazine adjacent to the chemical processing area, as shown in Figure 22. On the basis of the option tradeoffs, this facility is justified for inclusion in Phase B, at an estimated cost of $182,400.

IV.F. Subsystem Processing (cont)

2. Motor and Stage Assembly

Although the motor final assembly and stage assembly operations do not directly affect processing facility requirements, they must be considered in this effort because of the time assigned to these operations. It has been assumed that stage components will be attached to the maximum practical degree in the CCT caisson in order to minimize facility requirements at the launch site. These components are those located at the aft end which are accessable and most conveniently installed at the time of motor final assembly. The assembly process times were estimated to verify the overall process cycle time in the caisson, since the selection of only one additional CCT site is contingent upon the cycle time. A sketch of the motor assembly facilities arrangement is shown in Figure 27. The components to be installed are summarized below:

a. Motor Assembly

(1) Nozzle Throat Assembly
(2) Forward Exit Cone
(3) Aft Exit Cone
(4) Thrust Vector Control System (Movable Nozzle)
  (a) Actuators
  (b) Nitrogen Pressurant Tank
  (c) Gas Generator and Fuel Tanks
  (d) Auxiliary Power Unit
  (e) Hydraulic Reservoir and Accumulator
  (f) Electrical Power Supply
(5) Thrust Vector Control System (Liquid Injection)
  (a) Injector Manifold and Valves (Pre-Assembled to forward exit cone)

IV.F. Subsystem Processing (cont)

(b) Injectant and Pressurant Tankage and Supports (Pre-Assembled to Aft Flare Structure as Stage Assembly)

(c) Electrical Power Supply

(6) Thermal Insulation

b. Stage Assembly

(1) Aft Flare Structure

(2) Heat Shield

(3) Roll Control Motors

(4) Roll Control Propellant Tanks

(5) Roll Control Pressurant Tanks

V. SUMMARY OF RESULTS

A. PHASE A

1. For on-plant motor case handling, the road from the C-111 canal selected for Task I would be upgraded by paving, and an additional stiff-leg derrick would be required at the second CCT caisson.

Estimated cost: $712,000

2. No new facilities would be required for motor case handling.

3. For propellant processing and casting, a number of new facilities would be necessary, principally raw materials storage and handling facilities and equipment, improvements in fuel preparation and sample preparation, a new cast-cure-test caisson, and new casting equipment, buildings, and environmental systems.

Estimated cost: $4,347,000

V.A. Phase A (cont)

4. More permanent static test facilities would be required, including a modified instrumentation and control center, new personnel, utility, instrument and nozzle/TVC buildings, a new terminal room, and numerous instrumentation and special test equipment items to support both CCT facilities.

Estimated cost: $1,786,000 to $1,984,000

5. An ignition system and pyrotechnic magazine is required.

Estimated cost: $48,600

Total Phase A: $7,894,000 to $8,095,000

B. PHASE B

1. By utilizing anticipated facilities needed for loaded motor handling, the only item needed for case handling is a special transporter:

Estimated cost: $170,000

2. A new case insulation facility is justified by the need to minimize movement of the production cases fitted with the heavier handling rings.

Estimated cost: $886,000

3. An additional vertical batch mix station is needed to provide adequate reserve propellant production capacity.

V.B. Phase B (cont)

An additional set of oxidizer Tote bins is required to support the 30-motor program schedule. New CCT environmental shrouds are necessary.

Estimated cost: $2,228,000

4. An ignition system processing facility would be provided to efficiently utilize labor and propellant processing capacity.

Estimated cost: $182,400

Total Phase B: $3,466,000

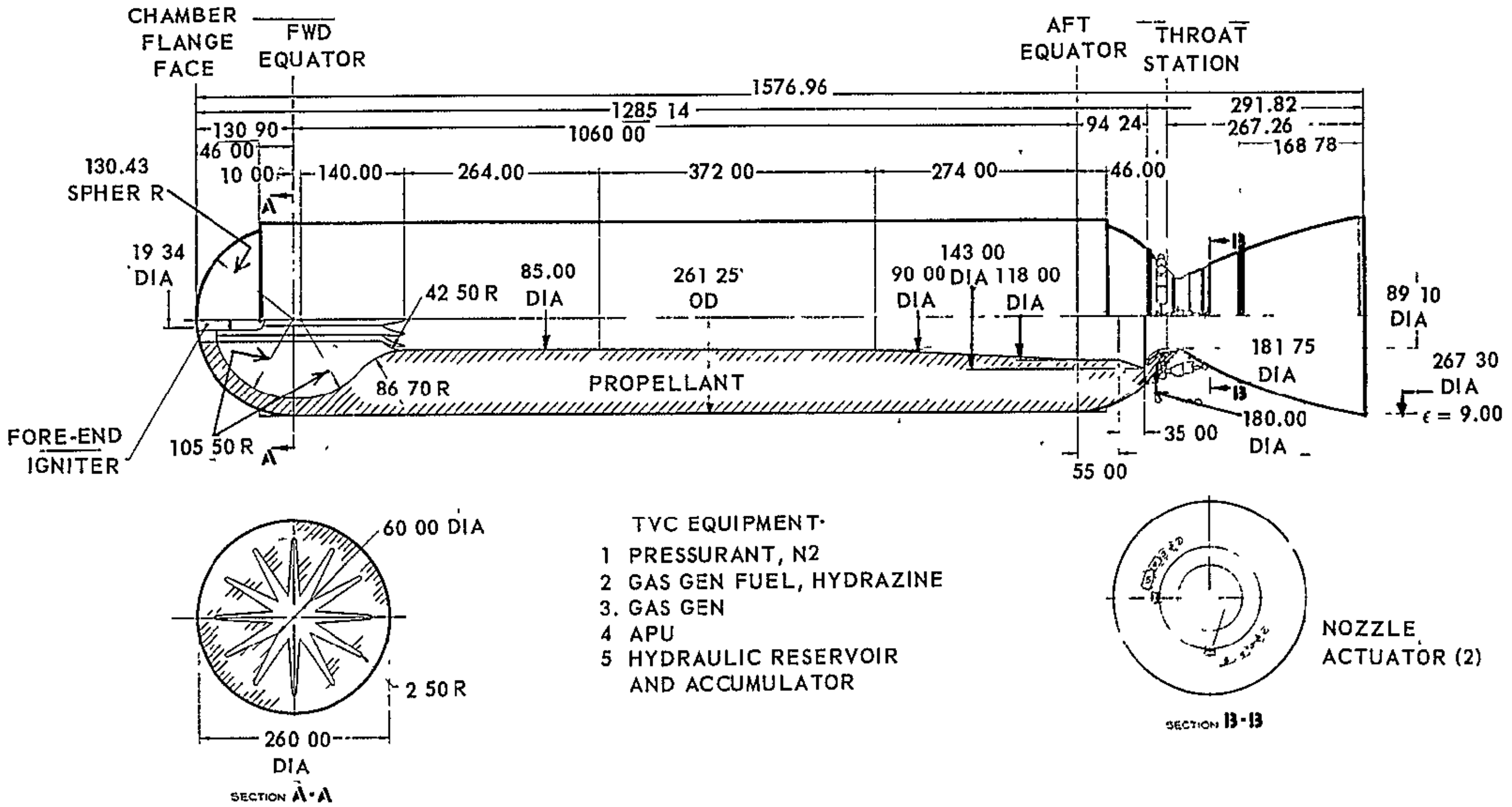
C. ALTERNATIVES

1. The total facilities outlay for Task I and Task II is in the range of $12,470,000 to $12,903,000. If the Task I program were eliminated, the total would be reduced by amounts of $118,000 to $141,000, for net totals of $12,352,000 to $12,762,000.

2. If Phases A and B of Task II were combined, and the Task I program eliminated, the total facilities cost would be $12,096,000 to $12,506,000.

3. In the event that static testing requirements were superimposed on the Phase B 30-motor program, an additional CCT facility would be required. This is due primarily to the schedule. In addition, environmental hazards imposed on the 2000-ton (1,800,000 Kg) double-boom derrick required for loaded motor lifting would necessitate disassembly of the derrick for static testing.

Figure 1



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260-in. Dia Full-Length Motor Assembly

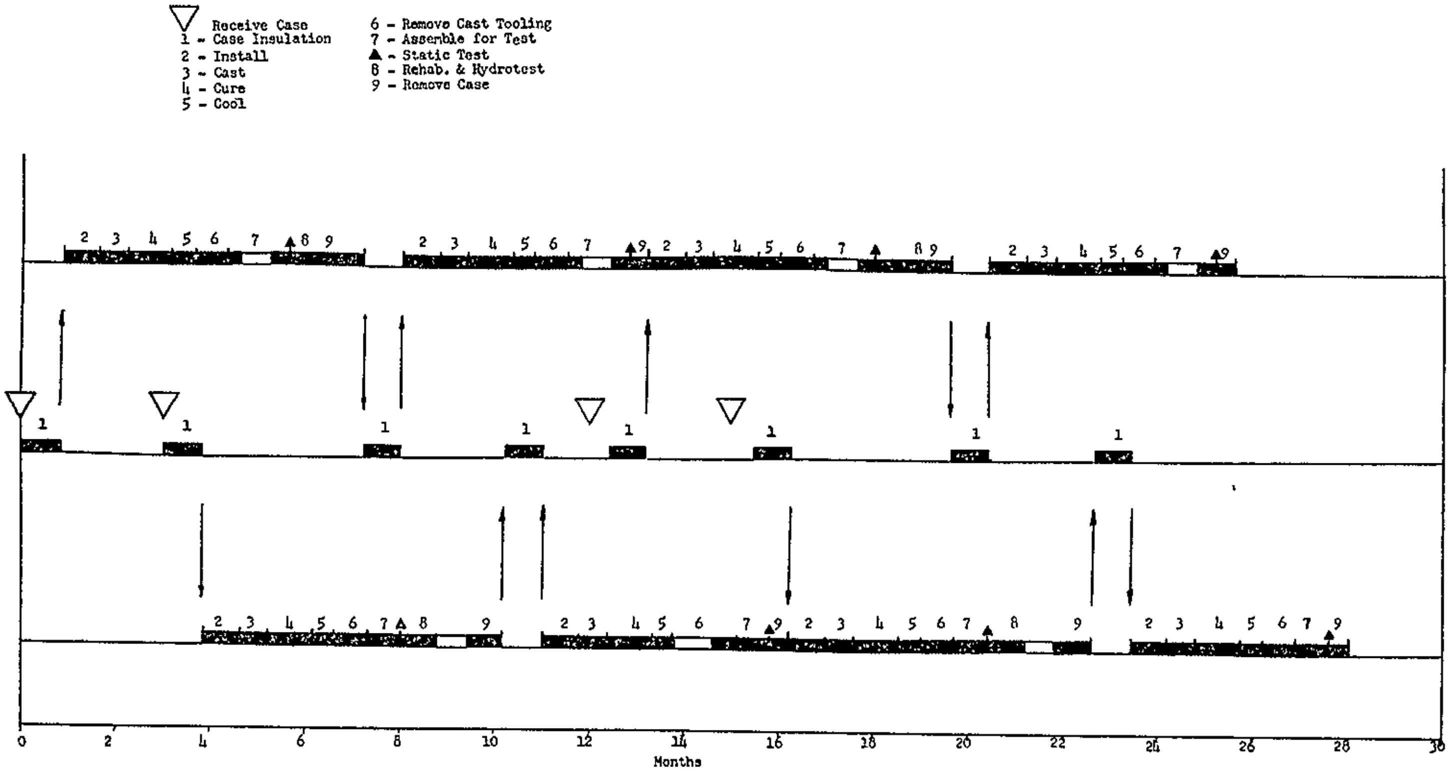
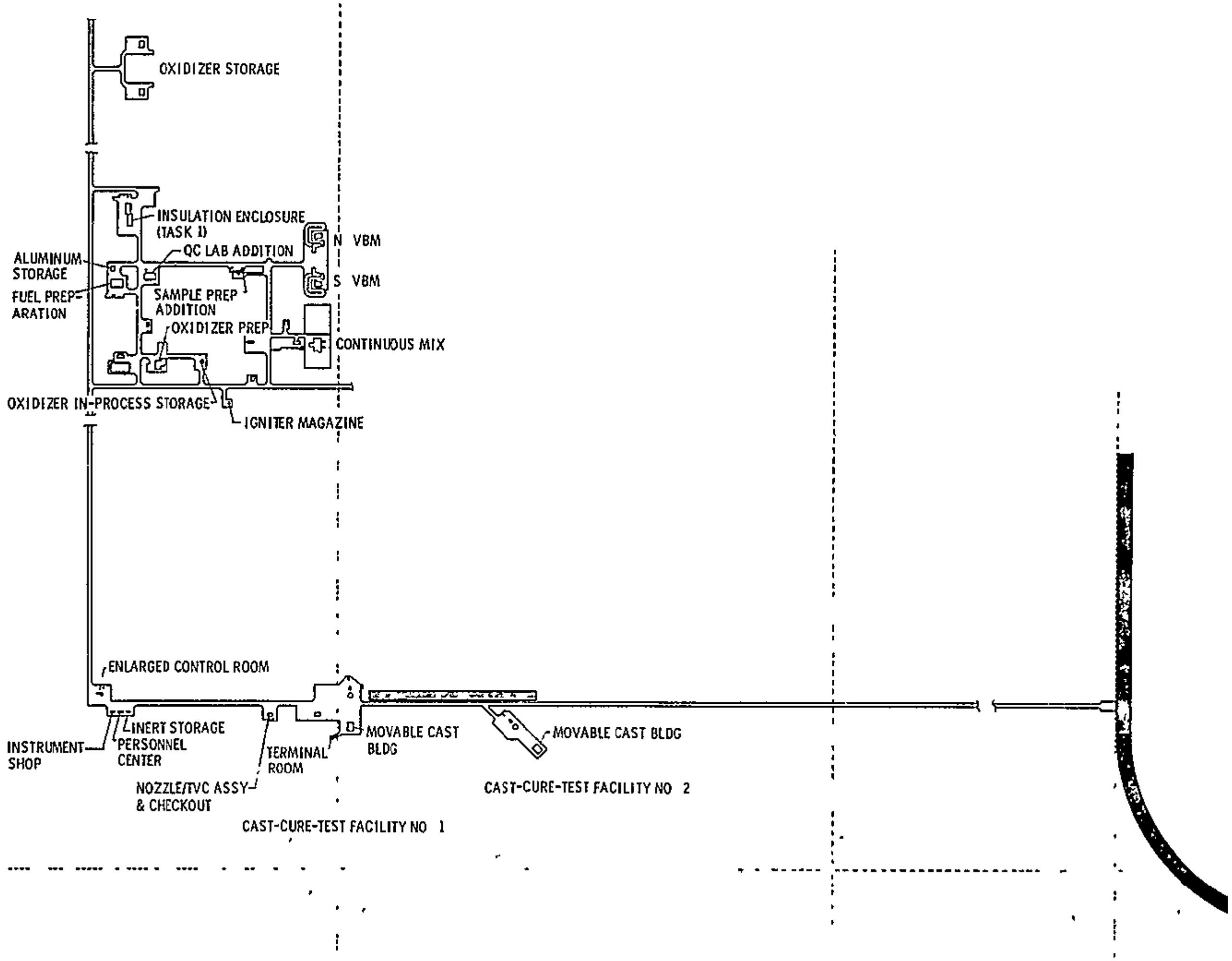


Figure 2

Task II - Phase A - 8 Motors in 2.5 Years

Figure 3



Task II - Phase A Facilities Arrangement

Location	Installed Weight, lb (kg)	No. of Batches	Batch Size, lb (kg)	Total Weight of Material Mixed, lb (kg)
Forward Dome	7,410 (3,361)	3	2,841 (1,288)	8,522 (3,860)
Aft Dome	11,005 (4,992)	5	2,531 (1,148)	12,656 (5,740)
Nozzle	5,065 (2,297)	2	2,913 (1,321)	5,826 (2,642)
Sidewall	16,630 (7,543)	7	2,732 (1,239)	19,124 (8,674)
Propellant Boots	4,535 (2,057)	2	2,608 (1,183)	5,216 (2,365)

Insulation Materials Requirements

Figure 4

Material	Storage Method	
	Task I	Recommended Changes
Ammonium Perchlorate	Tote bins stored outside	Store in weather tight structure
Aluminum	Drums; stored in fuel building warehouse	Tote bins; store in weather tight structure
PBAN	Tank cars	Agitated blend tank
DOA	Tank cars	Blend tank
Fe_2O_3	Moisture tight drums	None
Iron Blue	Moisture tight drums	None
Silicone Fluid	5 gal (0.019 m^3) metal cans	None
DER-332	55-gal (0.21 m^3) steel drums	Mone
FC-151	5-gal (0.019 m^3) cans	None
FC-167	50-lb (23 Kg) fiber drums	None
PBNA	50-lb (23 Kg) fiber drums	None

Propellant Raw Material Storage Summary

Figure 5

1. Size Basis: 3.4 million lb (1,540,000 Kg) propellant

   7% excess (scrap, qual., spillage, etc.)

   5% contingency

   9.5% PBAN in propellant

   7.8 lb/gal (0.93 gm/cm^3)

2. Size = (3,400,000) (1.07) (1.05) (0.095) 7.8) = 46,500 gallons (176 m^3)

3. Estimated Cost:

a.	304 stainless steel tank (includes agitator, insulation, concrete pad, material, installation and design labor costs)	$77,500
b.	Heat exchanger and pump (installed)	5,000
c.	Agitator motor and controls	5,000
	Total	$87,500

PBAN Blend Storage Tank

Figure 6

1. Size Basis: 3.4 M lb (1,540,000 kg) propellant

   7% excess (scrap, qual., spillage, etc.)

   5% contingency

   3.6% DOA in propellant

   7.7 lb/gal (0.92 gm/cm^3)

2. Size = (3,400,000) (1.07) (1.05) (0.036) (7.7) = 17,860 gal (67.5 m^3)

   Use 20,000 gallon (75.6 m^3) Tank

3. Estimated cost of type 304 stainless steel tank, unagitated, including concrete pad, installation and design labor cost is $24,000.

DOA Storage Tank

Figure 7

	Task I Method	Recommended Change
I. SUBMIX		
PBAN (terpolymer)	Weigh tank	None
DOA (plasticizer)	Weigh tank	None
Silicone Fluid	Manual dispensing and addition	None
FC-167 (Wetting Agent)	Manual dispensing and addition	None
II. PREMIX I		
Fe_2O_3	Procure dry material and pre-dispense into moisture tight drums; add through Syntron Feeder	None
Iron Blue	Same as Fe_2O_3	None
III. PREMIX II		
Aluminum	Weigh in drums; add through Syntron feeder	Weigh in Tote bin; add through feed screw/Sweco acreen
FC-151 (cure catalyst)	Manual dispensing and addition	No change
PBNA (antioxidant)	Manual dispensing and addition	No change

Premix Materials Handling Summary

Figure 8
Premix Materials Handling Summary

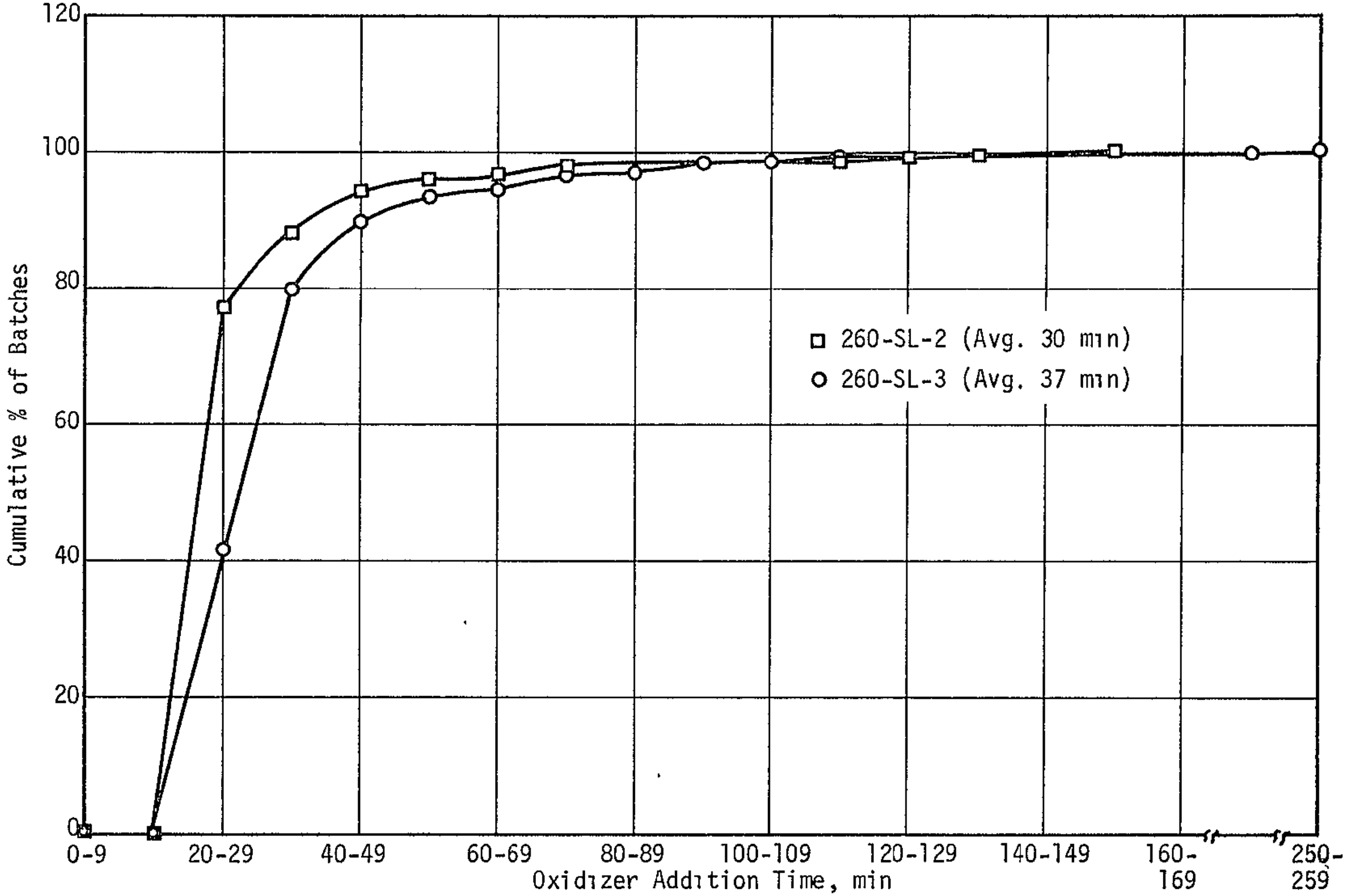


Figure 9

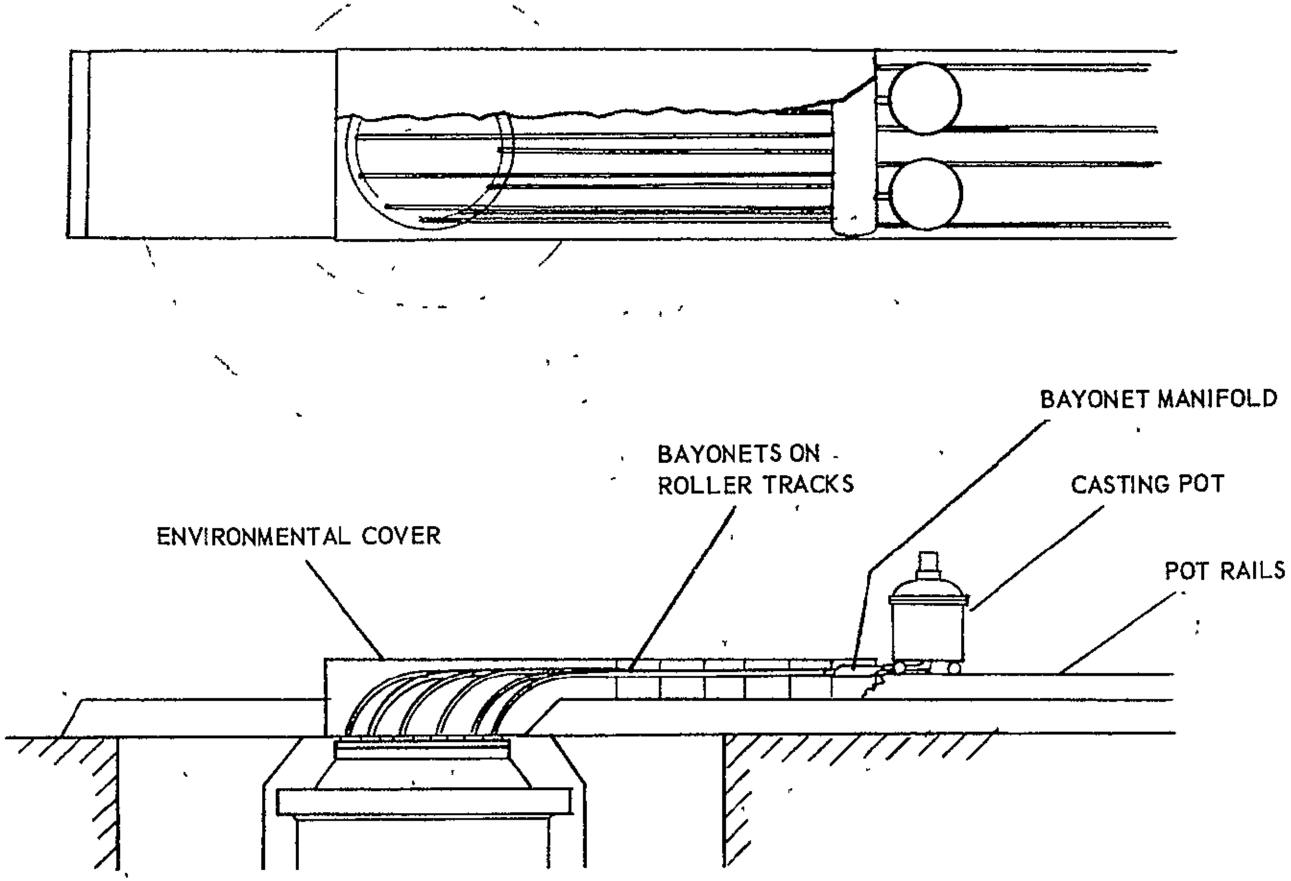
Oxidizer Addition Times for Vertical Batch Mixes

Method	Advantages	Disadvantages
A Distribution		
1 Propellant distributed from 1 to 3 pots connected to a single manifold which supplies 12 bayonets	a Casting time more efficient since capable of handling 1 to 3 pots. b. Simultaneous casting of 12 fins regardless of number of pots	a Single manifold more complex, larger and heavier to handle
2. Propellant distributed simultaneously from 3 pots, each connected to a manifold which supplies 4 bayonets	a. Manifold for 4 bayonets is smaller and easier to handle. b Bayonet arrangement more versatile.	a Casting must await 3 pots which is inefficient use of time and equipment b. Pot life is effectively shortened,
3 Manifold located near propellant pot	a. More accessible for assembly, disassembly and servicing b Easier to pig bayonets c Better visual monitoring of bayonets	a. Requires more tubing and bayonets b. More propellant to fill system
4. Manifold located near fin section.	a Can use non-reinforced, short bayonets, less expensive. b May not have to shorten bayonets, just shorten feed line between pot and manifold	a More complex manifold. b Two or more feed lines from pot to manifold to circumvent casting core c Difficult to service manifold and bayonet system d. Manifold would block visual monitoring of bayonets
B Bayonet Immersion Adjustment		
1 Liftout bayonets and shorten by cutting	a Simple installation and low initial cost b. Minimum pot lifting	a Considerable handling and bayonet cutting b Cannot be done within time schedule
2. Adjustable bayonet stands and tube spacers (spools)	a Minimizes number of bayonet removals and cuttings. b. Minimum pot movement.	a Many operations, time schedule crowded b Casting stand elevated above motor for use of spacers and bayonet stands Complex casting set-up
3 Lift manifold and bayonets vertically; pot on ground	a No bayonet shortening b Minimum pot movement c. Relatively low equipment cost. d Bayonet immersion depth controlled easily	a. Requires long duct between pot and manifold for propellant, and a thermal shroud b Requires hoist or lift device to accurately and safely adjust height c. Manifold and ducting not easily accessible for servicing.
4 Lift pot and bayonet system vertically.	a No bayonet shortening b. Bayonet immersion depth controlled easily c No bending of bayonets or propellant feed lines.	a. Requires expensive, complex elevator platform to lift entire casting system b Pot transfer to and from platform conducted at various heights
5 Move propellant pot and manifold horizontally while raising bayonets vertically.	a No bayonet shortening b Bayonet immersion depth controlled easily. c Minimum pot lifting d Fast, efficient and safe system	a. Requires 90 degree bending of bayonets or propellant feed lines, requiring special tube design. b. Complex guide system required to control horizontal and vertical bayonet movement

Propellant Casting Techniques, Fin Grain Section

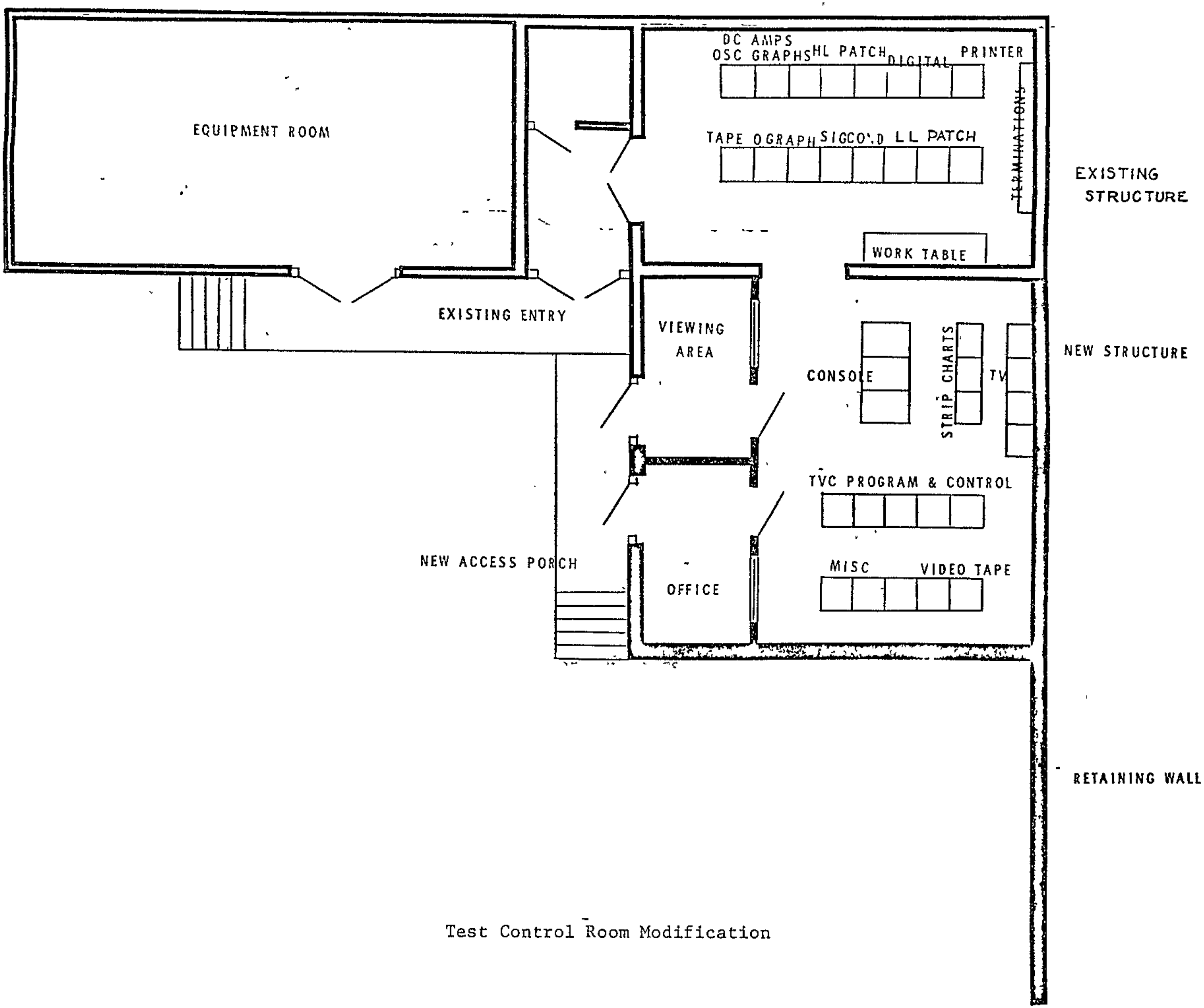
Figure 10

Figure 11



Improved Bayonet Casting Concept

Figure 12



Test Control Room Modification

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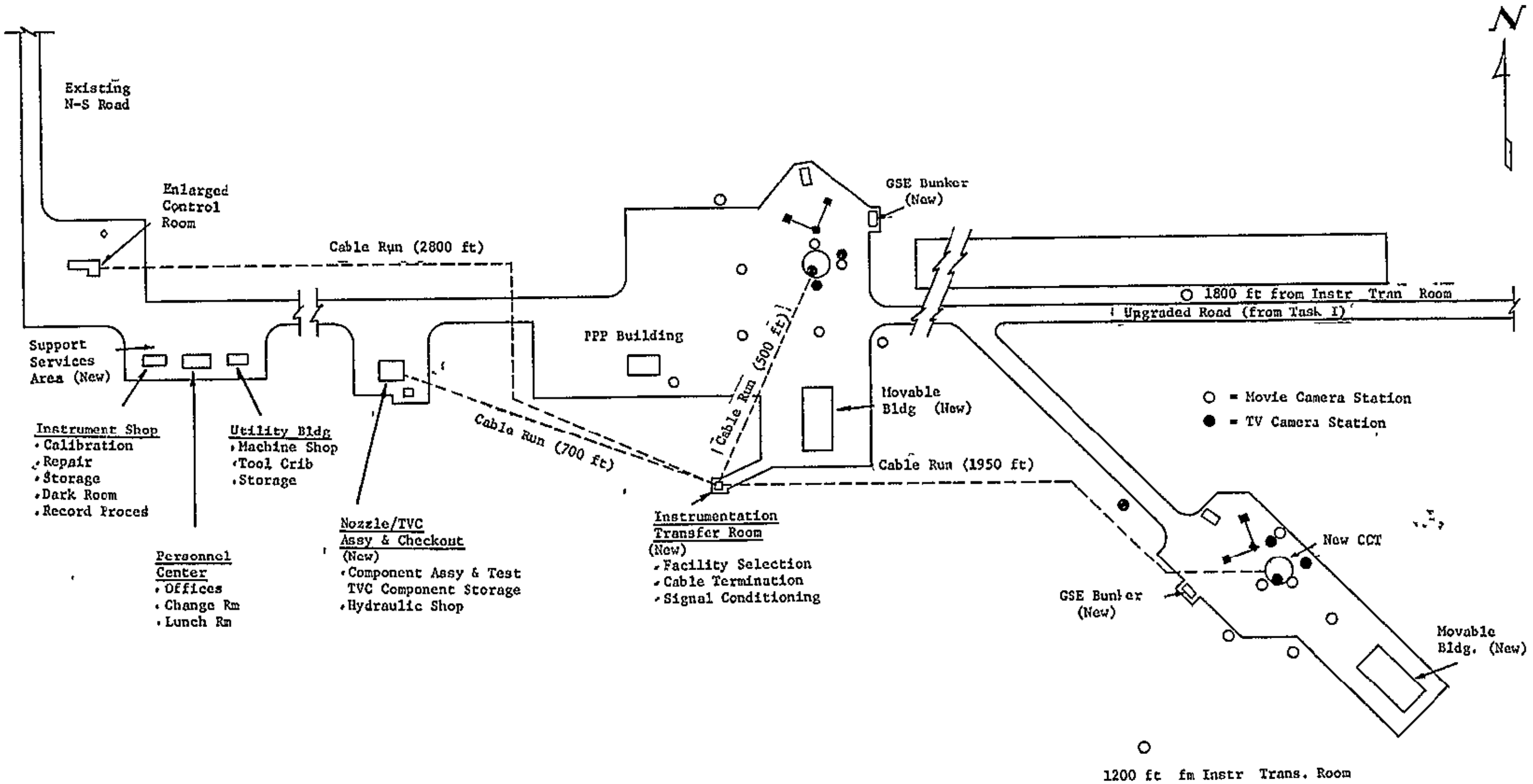

General Layout - Area 21 - 8 Motor Program

Figure 13

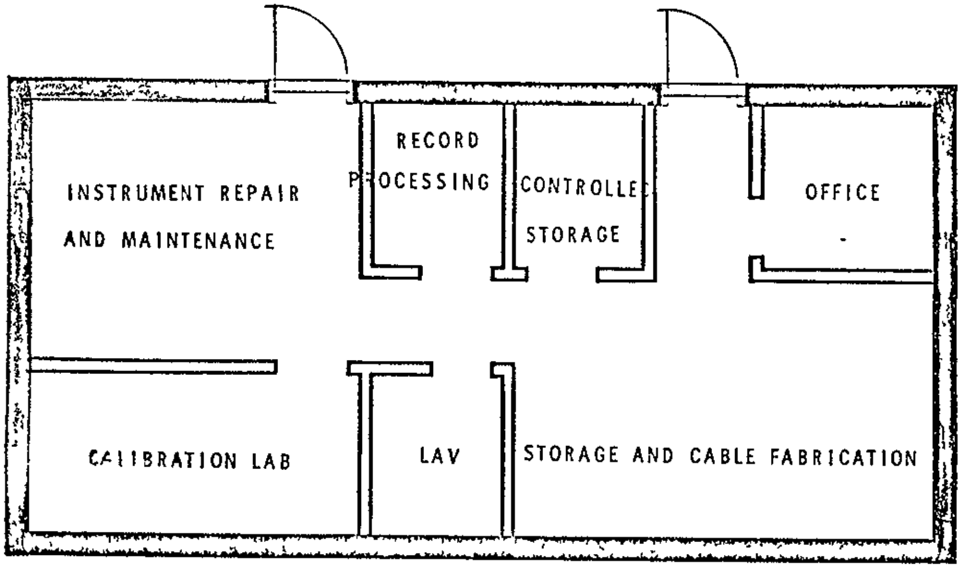

Figure 14

Instrument Shop

Figure 15

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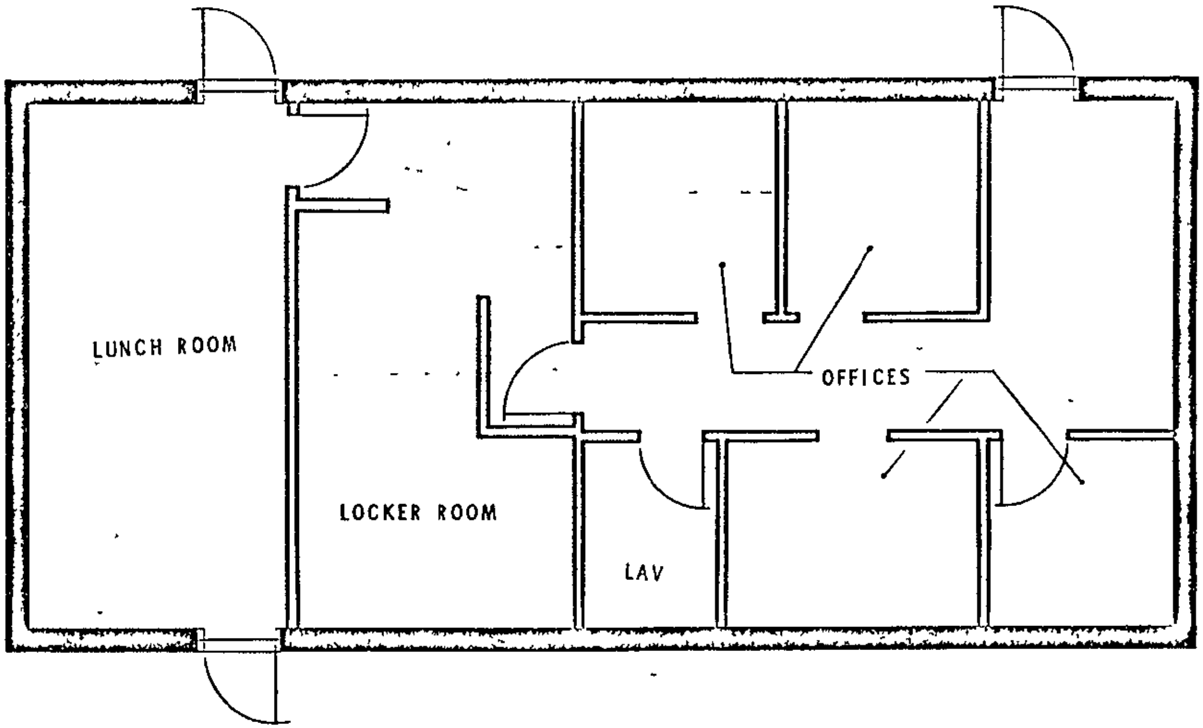

Personnel Center

Figure 16

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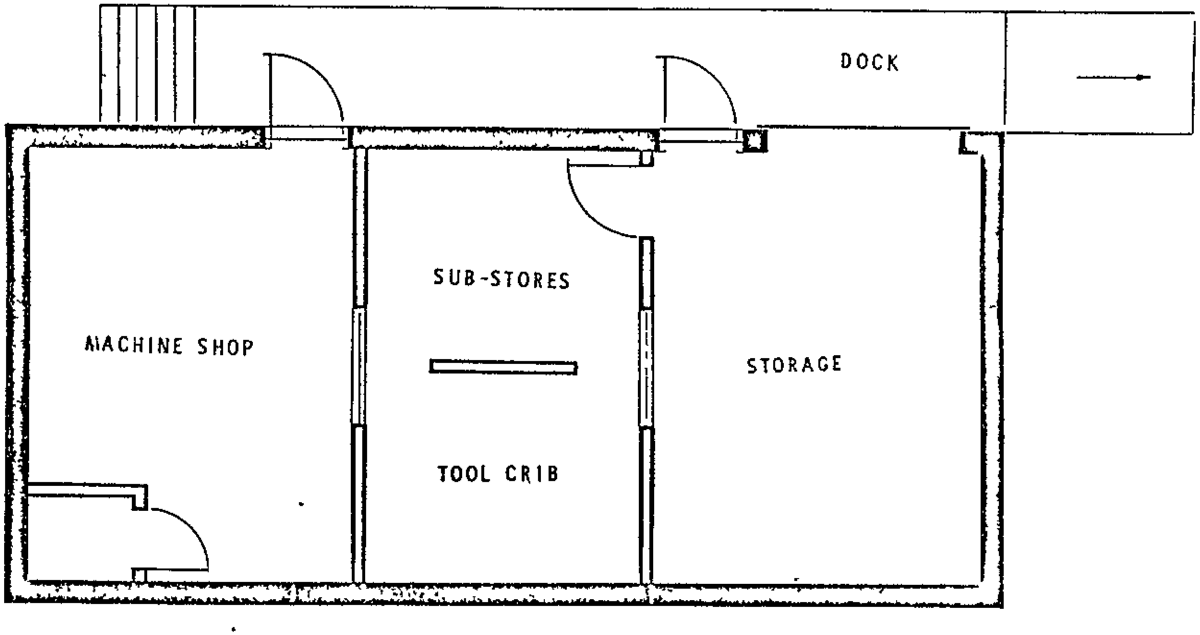


Utility Services Building

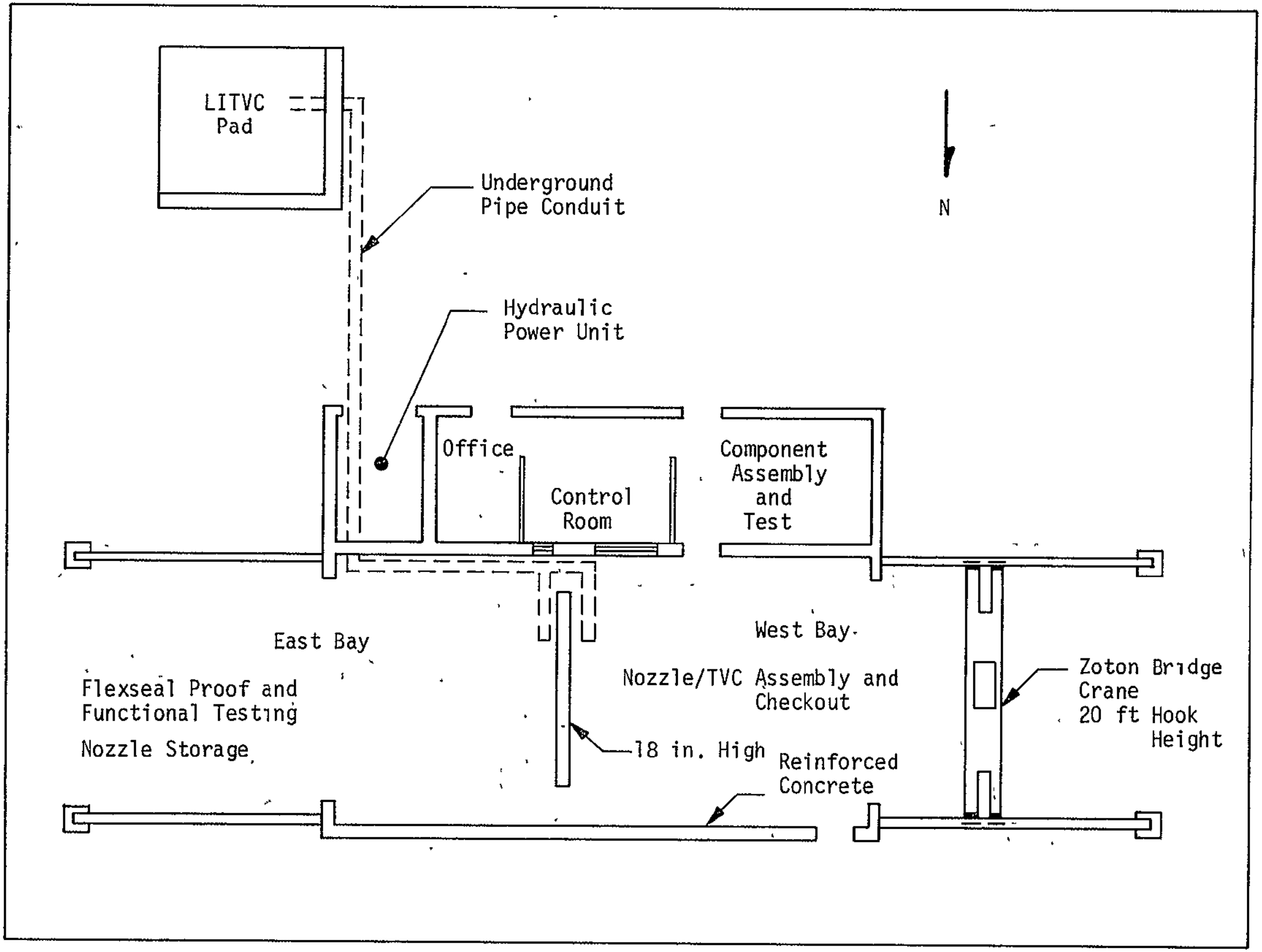
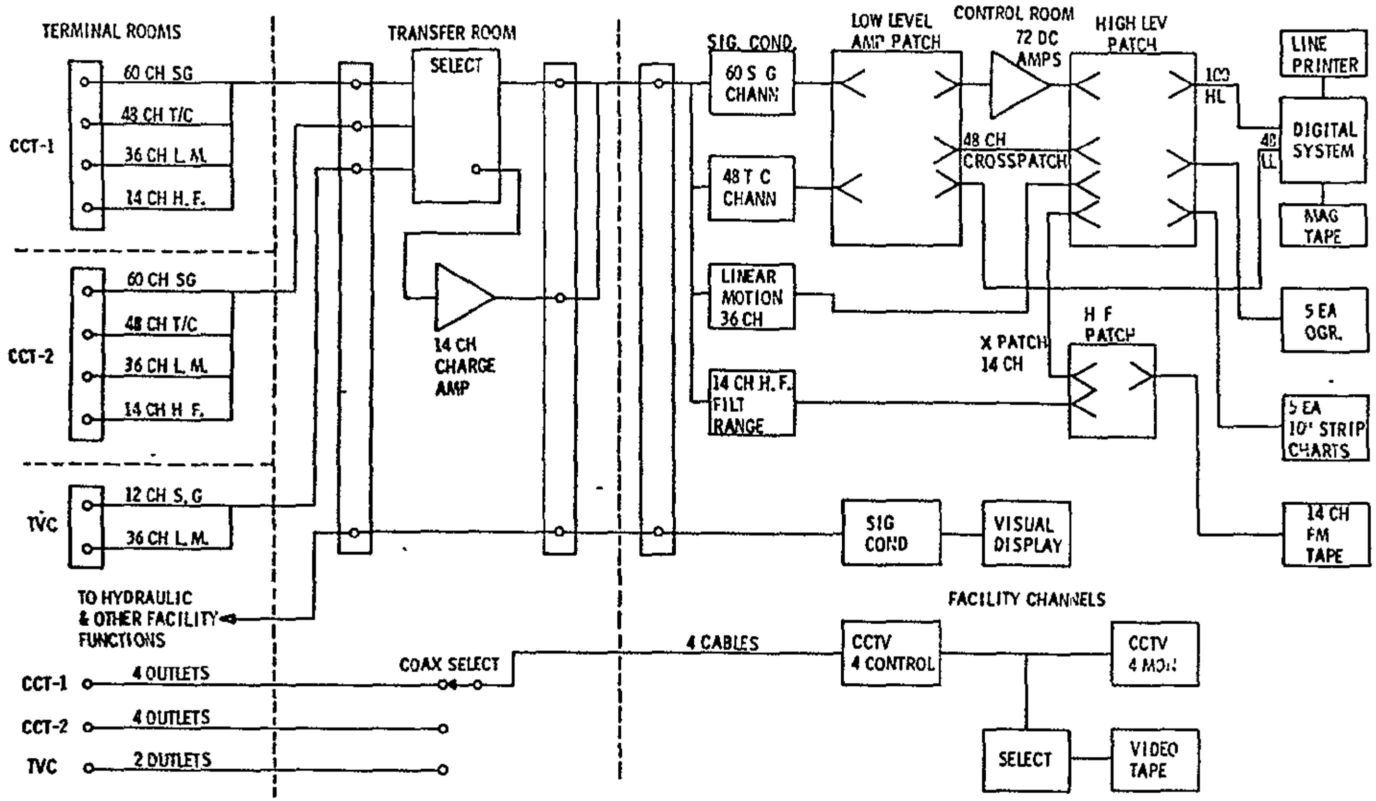


Figure 17

Nozzle Assembly and Checkout Building

Figure 18



DATA ACQUISITION BLOCK DIAGRAM

Data Acquisition Block Diagram

1. Acquisition	CCT-1, 2	TVC Assembly and Checkout Building
Strain Gage	60	12
Thermocouple	48	0
Linear Motion	36	36
High Frequency	14	0
Event	36	12
CCTV	4	2
Meteorological	4 Channels for facility	

2. Recording

Digital	100 high level 50 low level
Oscillograph	Up to 5 ea 36 ch
10 in. strip chart	5
10 in. multi-point	1 ea 8 point
FM tape	14 Channels, 20 KHz
Cameras	Up to 9
Elapsed time	1 ea, 1 m.s. resolution

3. Playback

Digital	Teletype line printer
FM tape	14 track to one of 5 oscillographs (1 oscillograph is direct-write for instant viewing).

Summary of Instrumentation Capabilities

Figure 19

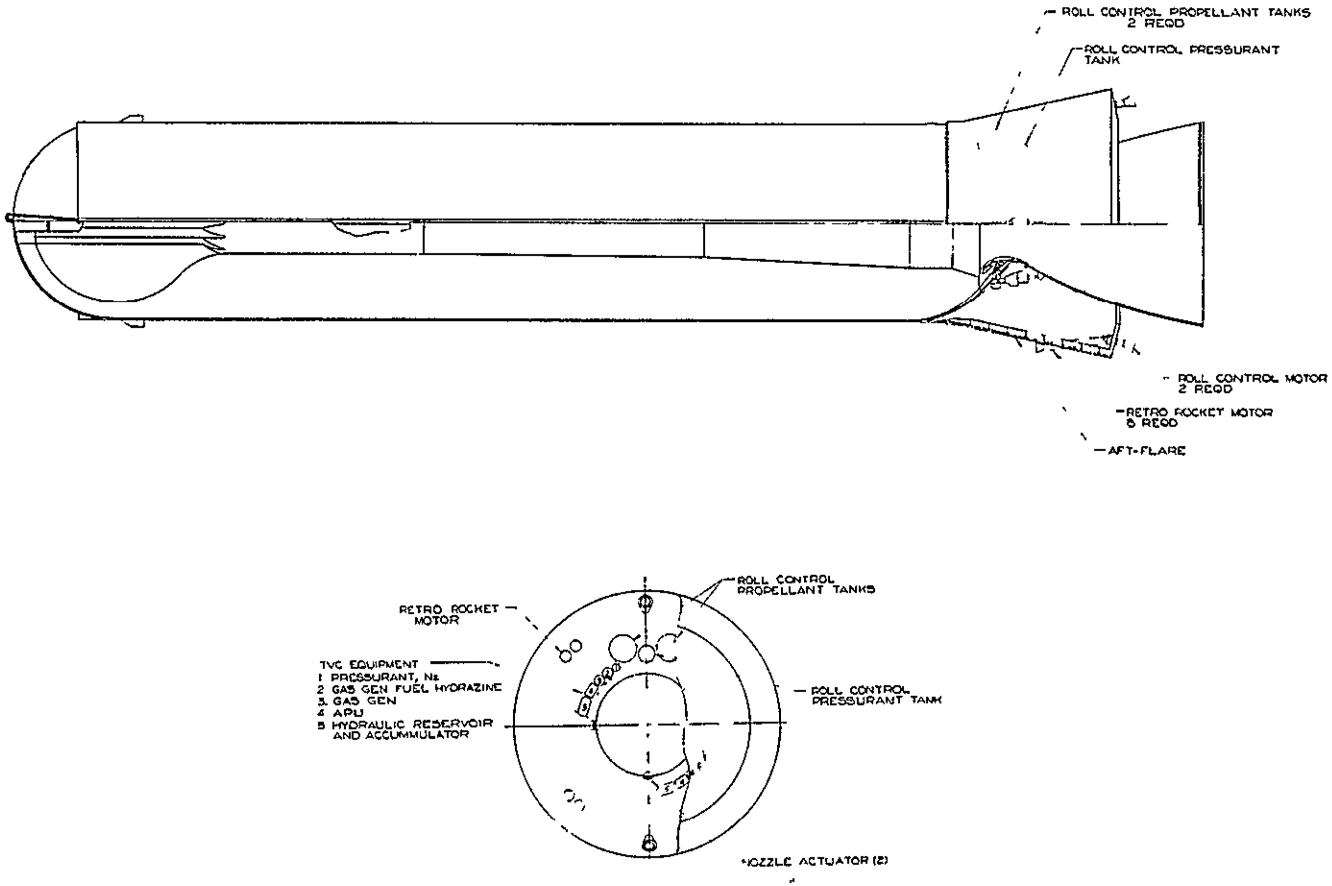
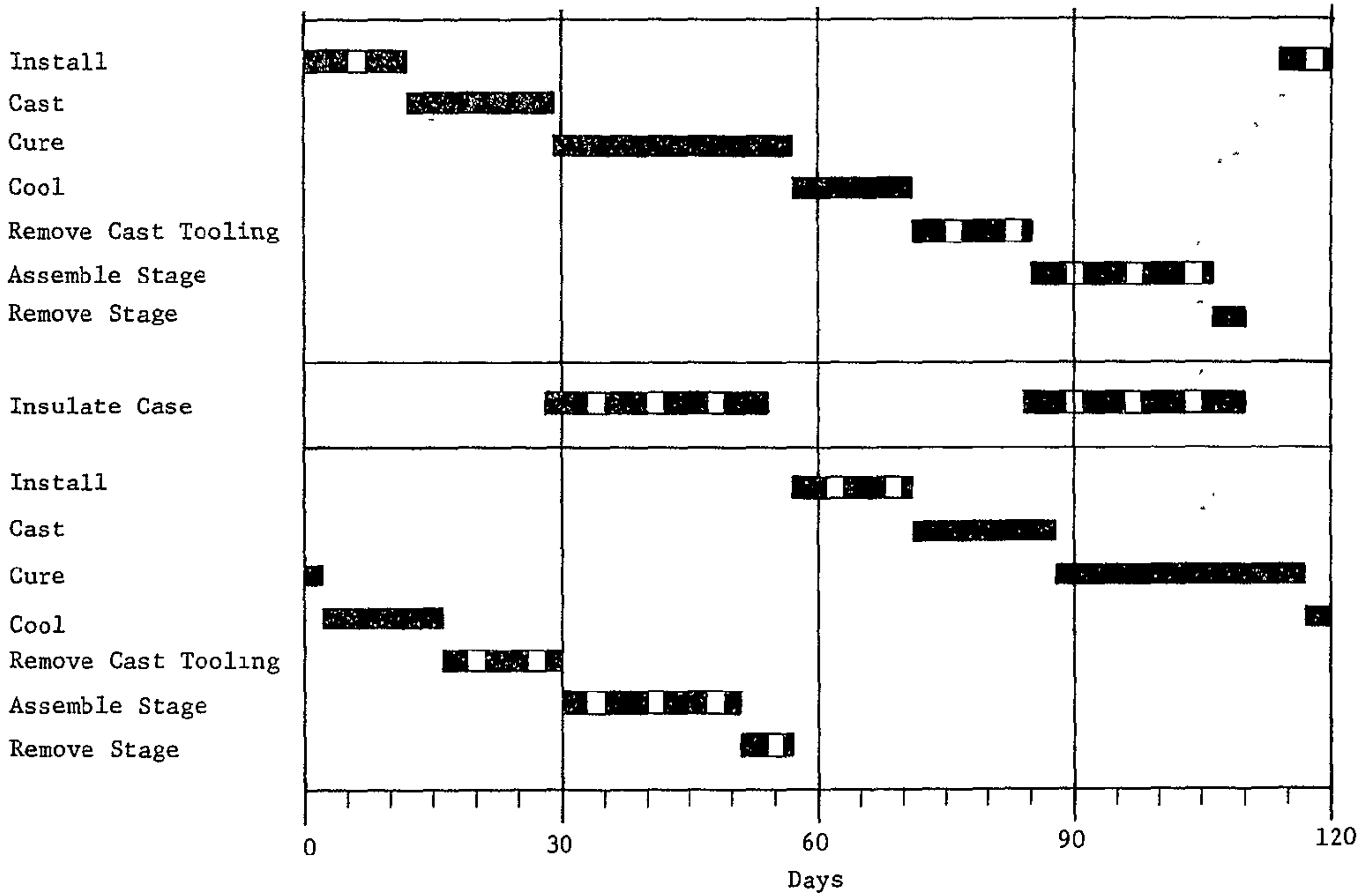


Figure 20

260-in. Stage Assembly



Task II, Phase B - 30 Motors in 5 Years

Figure 21

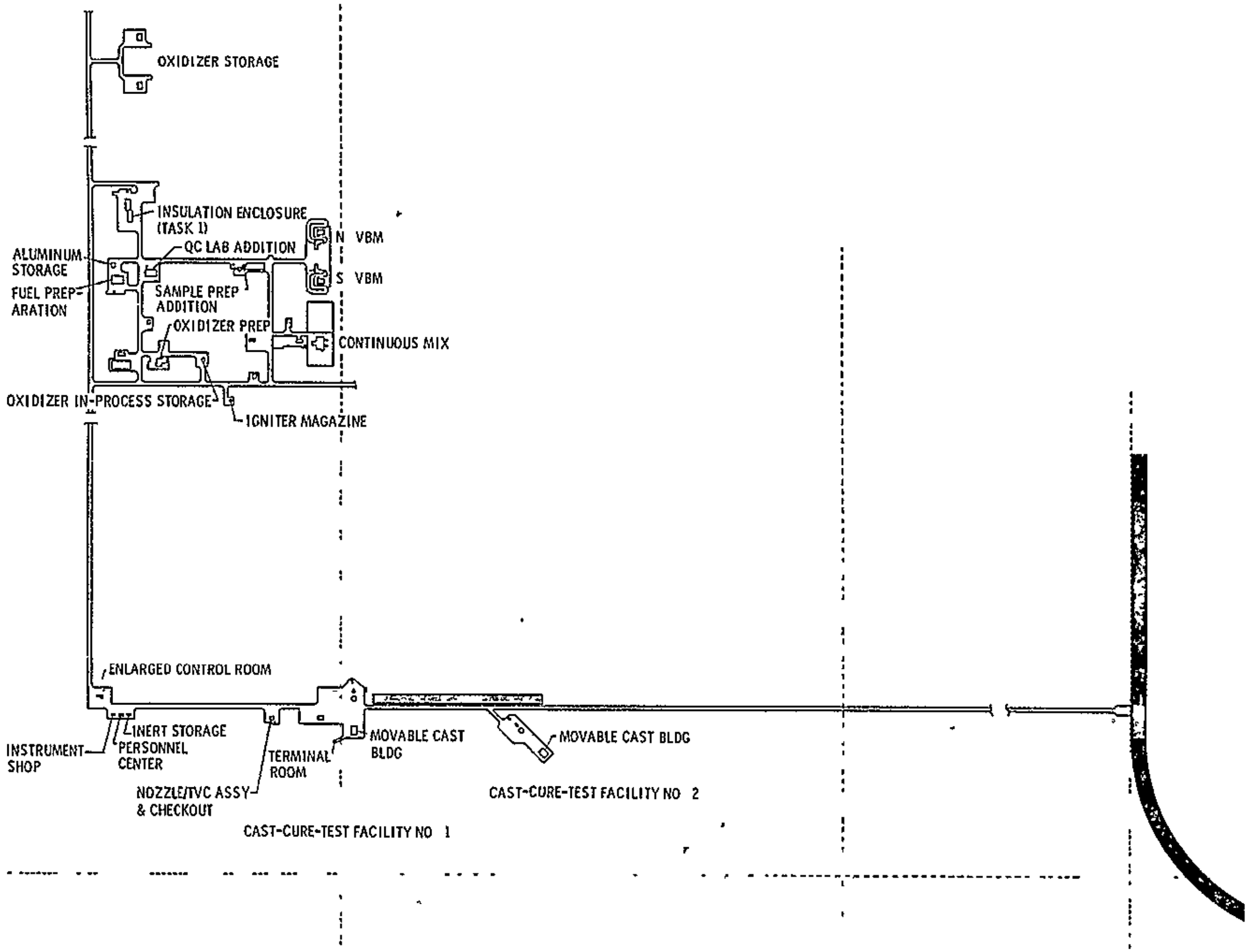


Figure 22

Task II - Phase A Facilities Arrangement

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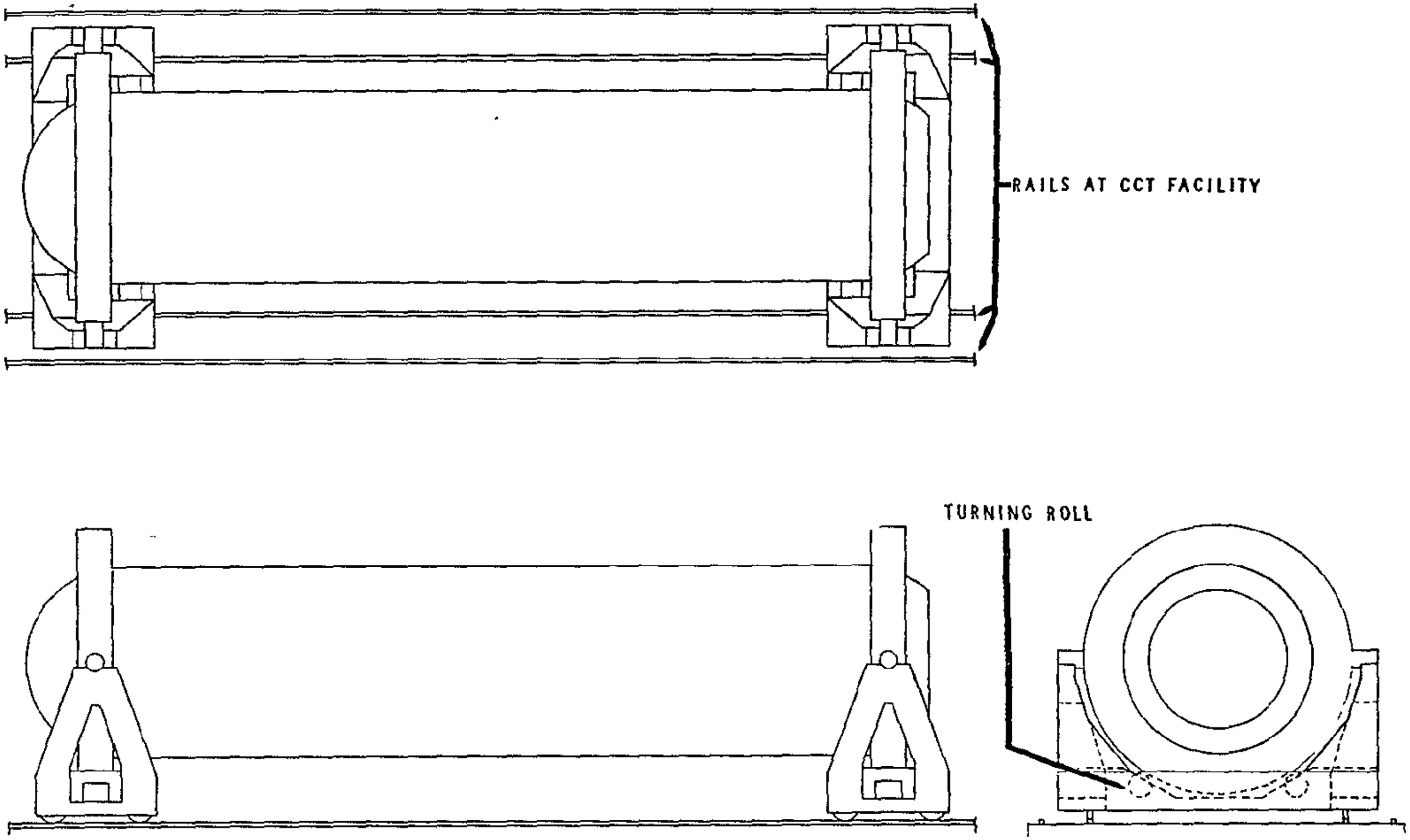
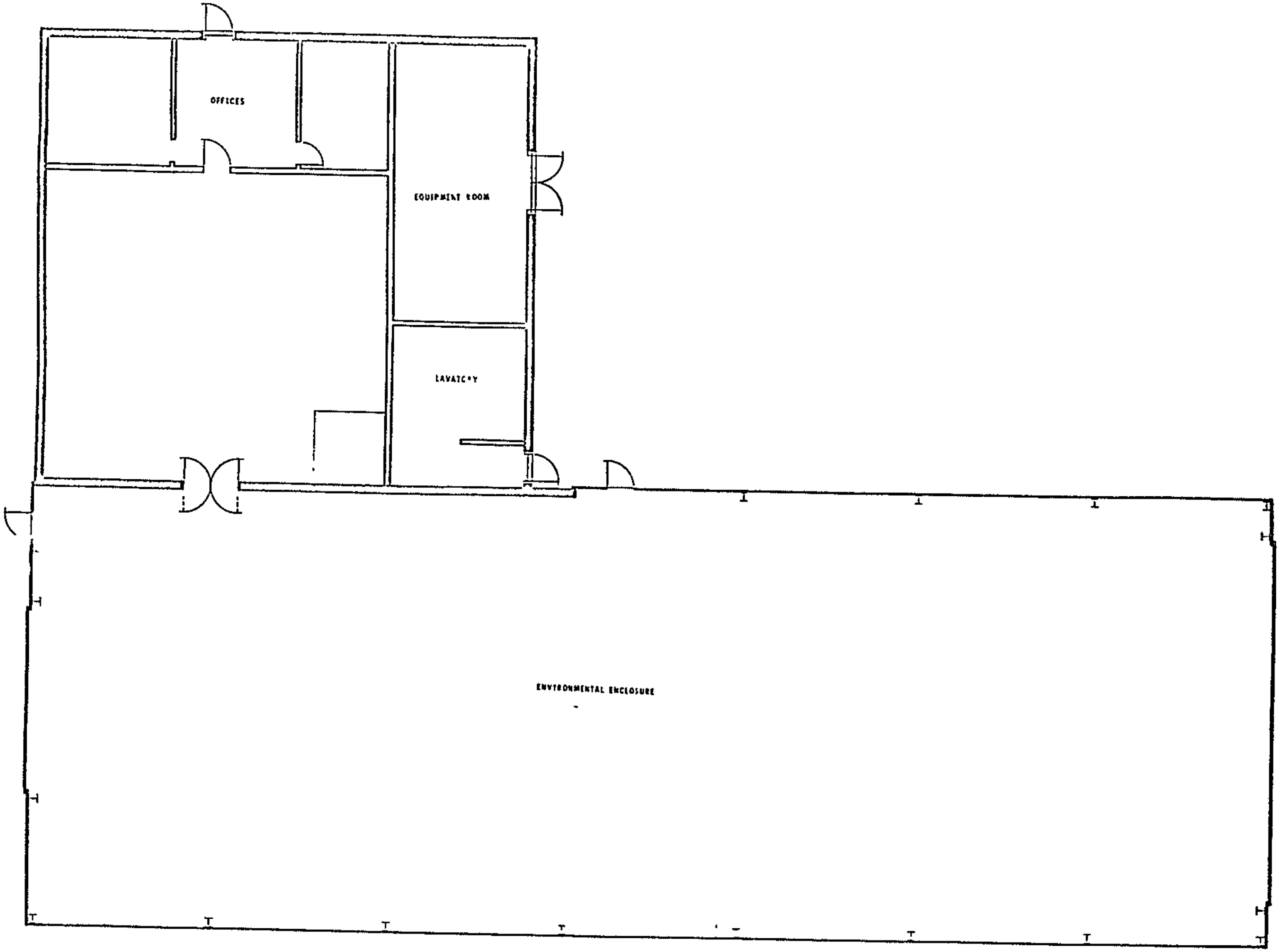


Figure 23

Transporter Concept for Phase B Case



Insulation Facility

Figure 24

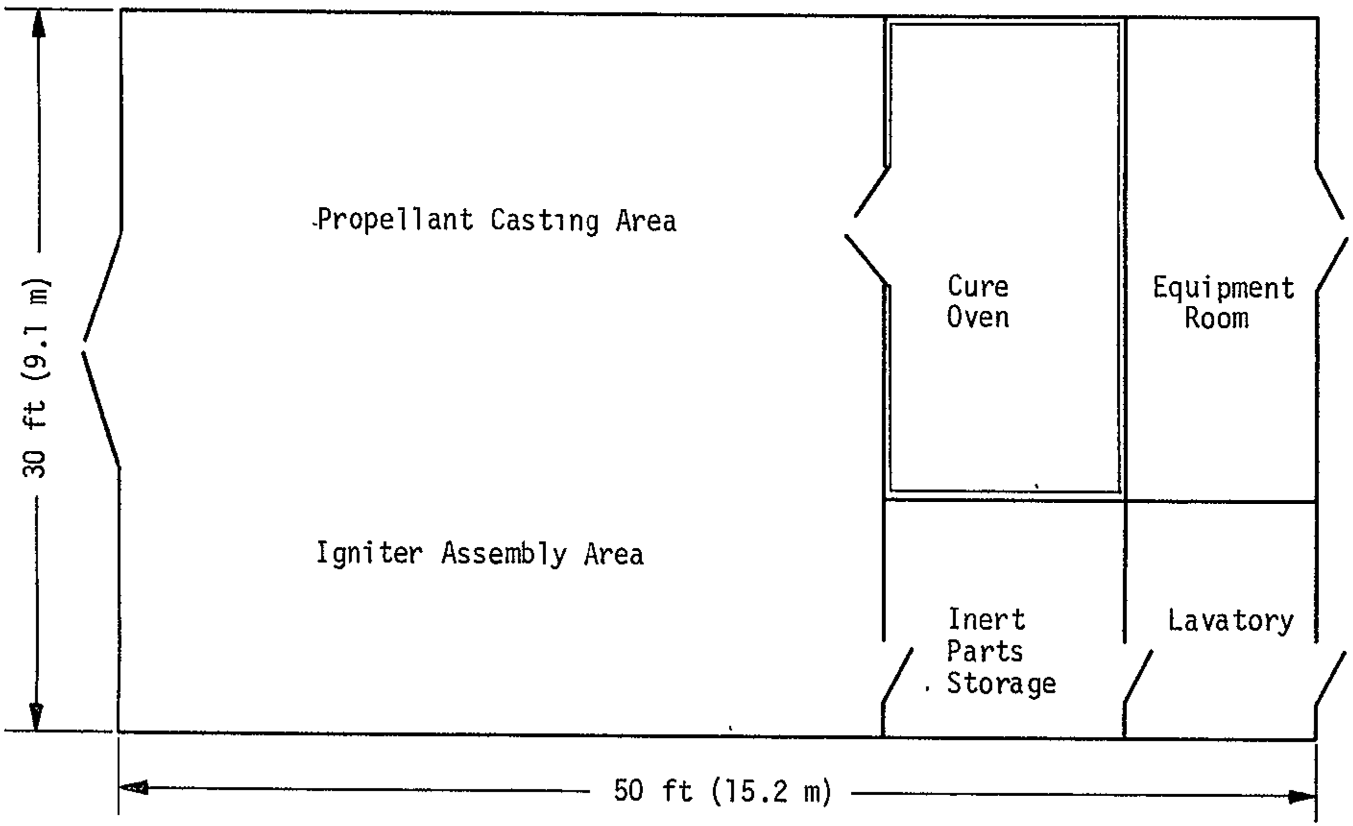
OPTION 1	OPTION 2	OPTION 3
Process and assemble ignition motor and booster at ASPC, Sacramento. Ship assembled ignition system to DCP.	Process ignition motor at DCP. Process and assemble booster at ASPC, Sacramento. Ship booster to DCP. Assemble ignition motor at DCP.	Process and assemble ignition system at DCP.

IGNITION MOTOR	HEAD-END	AFT-END
Propellant	ANB-3350	ANB-3350
Propellant installation	Displacement cast to configuration shown on SK 121365 or Tray-mold cast per AGC-36439 to configuration shown on 1005039.	Displacement cast to configuration shown on 1005130 or Tray-mold cast per AGC-36439 to configuration shown on 1005130.
Propellant weight, lb (kg)	280 (127)	950 (431)
Total ignition system weight, lb (kg)	2500 (1130)	4800 (2180)
Propellant grain length, in. (m)	70.4 (1.78)	112 (2.85)

IGNITION MOTOR BOOSTER SHOWN ON 1005039.

Task II-B, Igniter Processing

Figure 25



Igniter Processing Facility

Figure 26

Figure 27

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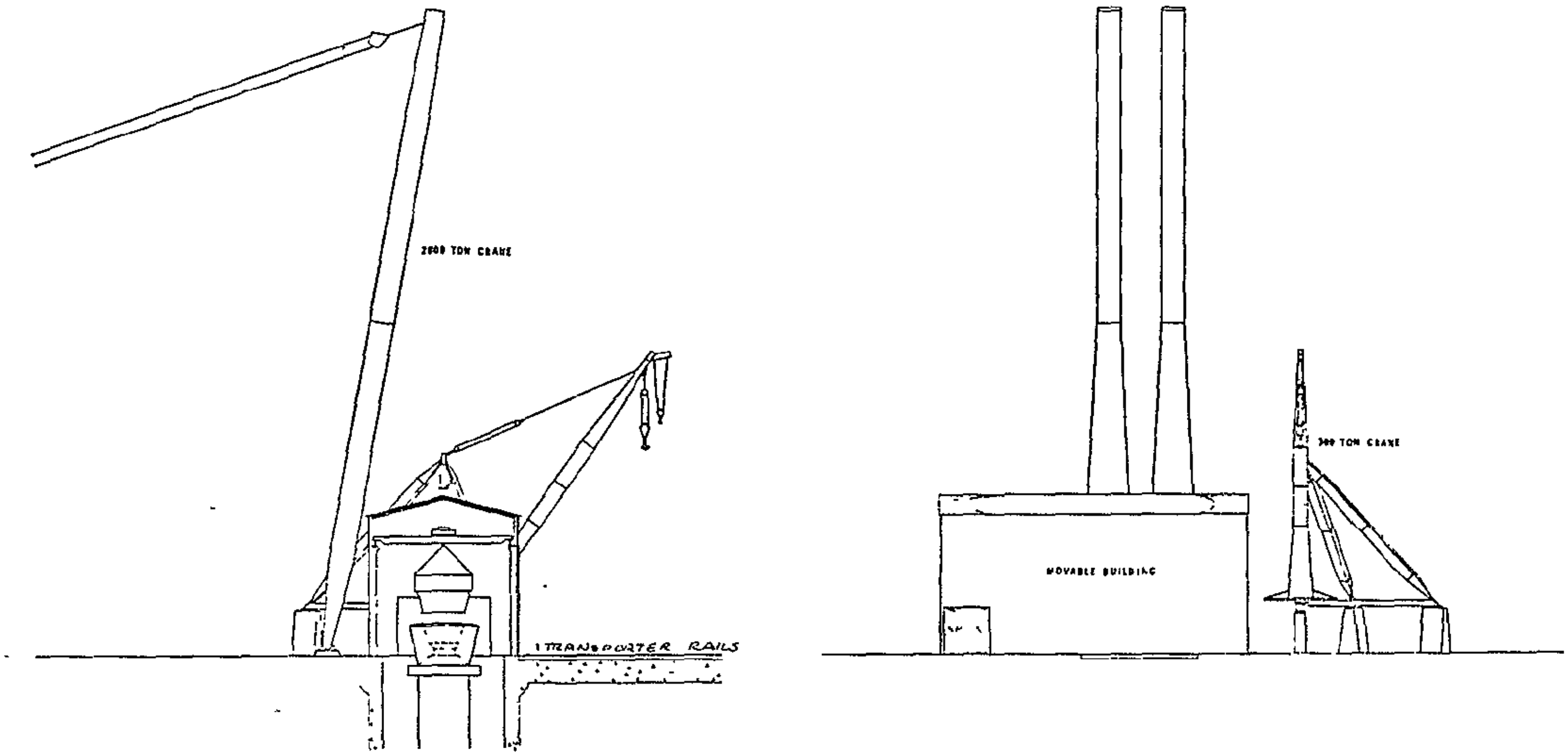

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